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16. ABSTRACT

Section 74 of the Clean Water Act of 1977 requires the Environmental Protection Agency (EPA) to investigate the ecological effects of seafood waste discharges and to identify treatment and waste utilization technologies applicable to seafood processing operations. As a result of this section of the Act this report was prepared and submitted to Congress.

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APPENDIX

VOLUME I

SECTION 74
SEAFOOD PROCESSING STUDY
EXECUTIVE SUMMARY

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July 14, 1978

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Washington, D. C. 20460

Dear Mr. Denit:

We would like to thank you, Mr. Schatzow, and Mr. Ng for meeting with us and other seafood processing industry representatives on June 16 to discuss EPA's implementation of the Section 74 Seafood Processing Wastes Study. We appreciate your taking time for this meeting which we believe was useful to us and trust that it was useful to you also. Many of the points discussed are summarized below.

It is the belief of the seafood processing industry that under certain conditions the discharge of wastes from seafood processing plants may be beneficial to marine life. Indeed, we believe these wastes can and do contribute to the development of a diversity of beneficial marine life species in the areas where they are discharged.

When the Congress conducted hearings on the amendment of the Water Pollution Control Act, representatives of the seafood processing industry testified and met individually with many congressmen, senators, and their staffs. Seafood processing industry representatives presented the view that where there is sufficient flow and aquatic life, the discharge of seafood processing wastes (which are of themselves non-toxic and non-harmful) should be allowed, in fact encouraged, to promote the development of aquatic resources. Industry representatives also expressed the view that where unreasonable, adverse effects on the environment result from the discharge of such wastes, adequate controls be instituted.

When Congress completed its deliberations on amending the Water Pollution Control Act, the final bill, PL 95-217, the Clean Water Act, contained a requirement for the Environmental Protection Agency to "examine the geographical, hydrological, and biological characteristics of marine waters to determine the effects of seafood processes which dispose of untreated, natural wastes into such waters."

The Conference Report on Section 74 clearly states that the conferees intended that the study include an examination of the "compatibility" of seafood wastes with marine waters. Senator Gravel in the December 15 Congressional Record debate on the Conference Report stated that the focus of the study should be ". . . to determine whether there are grounds for relief from the EPA effluent guidelines for the industry." Senator Gravel also stated in the August 4 Congressional Record that the study ". . . would delve into the question of what organisms or other fish or mammal life feed on the wastes and at what rates of consumption." He further stated that the study ". . . would discuss . . . the flushing effects of tides and currents . . . ," and that ". . . the study would be incomplete without a thorough analysis of the plausibility and environmental effect of moving the outfall line to eliminate the problem of accumulation of wastes."

The seafood processing community was pleased that the Congress, by approving the Section 74 Seafood Study, recognized the merits in the industry's views and arguments on compatibility with and bio-enhancement of marine life due to the discharge of seafood processing wastes. Consequently, the industry viewed the requirement for EPA to conduct the seafood processing study as a means of determining once and for all the validity of its claim.

For implementation purposes, the Agency has divided the Congressionally-mandated study into two parts. We have already commented favorably on the undertaking of the market feasibility study for seafood waste reduction in Alaska. This letter is mostly concerned with the effects of the discharge of effluents from seafood processing plants on marine life.

In implementing the second part, according to EPA papers and your comments at our June 16 meeting, the Agency will

. obtain new field data on the water quality effect of "untreated natural wastes" from seafood processing only in Alaska and one control site in Oregon;

. examine technologies to facilitate the use of nutrients in these wastes or to reduce their discharge into the marine environment; and

. conduct a literature review of the discharge of seafood processing wastes.

To implement the above objectives, EPA developed a work plan to be undertaken and completed by private consultants, the University of Alaska, and the Effluent Guidelines and Research and Development segments of EPA. The work plan consists of the following parts:

. A literature search to compile available historical data relating to water quality work both in Alaska and the forty-eight states;

. A detailed assessment of various technologies which may be used in treatment, recovery, or disposal;

. An assessment of the economic feasibility of the manufacture of by-products from seafood processing wastes; and

. Visits to sites in Alaska and one site in Oregon to examine the geological, hydrological, and biological characteristics of the receiving water (the field work will include biological effects on bottom deposits, water column analysis, and scuba diving to observe macro flora and fauna and evidence of accumulation of deposits of seafood wastes).

The Agency has interpreted the term "untreated, natural wastes" to mean only discharges containing gross or ground solids. According to this interpretation, EPA has assumed that new water quality and marine effects data need only be conducted in the Northwest, since all other parts of the country apply a minimum of screening treatment. We do not agree with the Agency's interpretation. We believe that Congress intended screened effluents to be included in the new field work studies.

Contrary to EPA views, we believe that field work should also be done in other areas of the seafood processing industry, namely, bottom fish, sardines, shrimp, and tuna. Field work should be scheduled in Southern California, the center of the United States tuna processing industry; in Louisiana, the center of the United States shrimp canning industry, and in Maine and Massachusetts, the center of the United States sardine and bottom fish industries.

Clearly, the study was to be national in nature. Nothing in the language of Section 74 limits field work to one section of the country. In fact, according to an EPA March 3 memo, EPA was directed by the staffs of Senators Chafee and Gravel ". . . that the study should include coverage of all seafood processing, not just the Alaskan industry."

By failing to institute a thorough work plan for site visits to other areas of the country, new data will not be obtained to demonstrate that bio-enhancement can indeed occur under certain circumstances. Failure to obtain this data may result in arbitrarily stringent regulations requiring "treatment for treatment sake" costing the affected industries many millions of dollars for no environmental benefit and perhaps a loss in marine improvement. If the data are obtained to demonstrate that bio-enhancement does indeed occur, the Congress in evaluating the report might determine at some future date that technology-based standards need not apply to seafood processors under certain specified conditions. This approach was taken by the Congress when it granted municipalities an opportunity to apply for a waiver for secondary treatment requirements based on discharge into marine waters. It was also taken in the Ocean Dumping Act, where seafood wastes are excluded from its provisions.

We acknowledge the below statement from your March 3 memo on the seafood study that under existing law "Regardless of what we do, accomplishment and utilization of any kind of water quality review or assessment is legally inconsistent with Title III of the Act;" however, this statement and a similar one made by Agency representatives during the June 16 meeting does not reflect the intent of the study, which is to provide a report to Congress containing a full cycle thorough review of seafood discharges to determine their compatibility with marine waters.

We believe that the major thrust of the study should be to thoroughly evaluate the industry's claim of the compatbility and bio-enhancement effects of seafood wastes so that Congress can base its future deliberations on this subject with a full understanding of the issues involved. The study should not be based on the premise that the law will remain the same, as your statements suggest.

We disagree with the following statement from your March 3 memo:

> "The request for additional studies in Los Angeles harbor should be a moot point since all tuna canning effluents have been diverted to the local POTW."

This statement again assumes that the existing situation should be continued. We believe that the Agency should conduct new field work in the harbor to determine any changes in marine life that have occurred as a result of the canneries ceasing their discharges. Did the diversity of marine life increase or decrease? What happened to the dissolved oxygen levels? Answers to these questions should be included in the report to Congress. This statement is also contrary to the intent of Congressman Anderson of California who stated in floor debate that "this study should include an assessment of the discharges from such canneries into Los Angeles harbor." (Congressional Record, December 15, 1977.)

We are also concerned that the Agency is failing to complete "full-cycle" studies of the impact of seafood processing wastes on marine waters. In our view, it is inappropriate for the Agency to conduct a one or two day site visit and then claim or assume that this site visit represents typical conditions present at the site at all times. An effective study should begin with sampling prior to seasonal seafood plant start-up, at several times during the processing season, and for a period of time after the plant is no longer in operation. Year-to-year comparisons should also be made.

From information provided to us by EPA, we are very much concerned that too much emphasis is being placed on the collection of data to support past rule-making and future enforcement efforts. On page 8 of the EPA March 3 letter, one of the con statements for conducting no new water quality field work was that "by eliminating new field efforts the Agency may miss water quality data which would assist the regional enforcement efforts." On page 6 of your March 3 memo, one of the pros for conducting more water quality/marine effects studies is "detailed ecological studies may identify more or chronic water quality problems, which may justify more than BAT for some areas in case-by-case permit situations."

Another indication of the Agency's emphasis on rulemaking and enforcement is contained in an EPA summary of the seafood study sent on May 25 to House and Senate Public Works Committees. The summary states that site visits will be made "to problem areas on the Atlantic and Gulf Coasts." Rather than focusing on "problem areas," to which sufficient attention has already been given, we believe the majority of the site visits should be made to "non-problem areas" to determine the beneficial aspects of the discharges and the conditions at these sites that Congress might wish to consider in its future deliberations.

Further evidence of the Agency's intention to use the study in support of rulemaking and enforcement efforts is found in the Agency's April 5, 1978 Research Proposal for Marine effects field work at Yaquina Bay, Oregon. According to this proposal:

> "The principal objective of this project is to assess the detrimental ecological impact, if any exists, of the cannery effluents . . . The regulatory significance is two-fold. First, environmental conditions in Yaquina Bay can serve as a comparison for the effects of cannery effluents from seafood plants in Alaska . . . Second, an analysis of the ecological impact of the Yaquina plants can contribute to the scientific basis for regulatory decisions concerning the need for effluent treatment beyond screening."

Obviously, this research is not objective. Its stated purpose is to find "detrimental" effects and to use the results of the study for increased regulatory requirements.

From the materials presented to industry to date, it does not appear that the Agency has taken any positive steps to determine under what conditions effluents from seafood processing plants may enhance the marine environment.

We were pleased to hear you and Mr. Schatzow comment in the June 16 meeting that the statements referred to above erred in that the referenced documents did not fully explain that compatibility and bio-enhancement effects of seafood wastes on marine waters were indeed being investigated. However, we would appreciate receiving additional assurances from your offices to this effect.

We recognize the limitations that the Agency has with respect to timing and the limited amount of resources available to conduct the study. However, we do not agree that the limited work plan being implemented is sufficient, particularly with respect to demonstrating compatibility of seafood processing wastes with marine waters or their beneficial effects on marine life. Our recommendation is that the Agency develop a more complete work plan, along the lines suggested by seafood processing industry representatives on January 27, 1978, and request additional time and resources from Congress to implement it.

In conclusion, we believe the Agency is failing to carry out the Congressional intent of the Section 74 Seafood Processing Study. We respectfully request that the program be redirected to focus on the beneficial aspects of the disposal of seafood processing wastes and that the rulemaking and enforcement aspects of the Agency's regulatory programs be separated from the seafood study.

Representatives of the seafood processing industry stand ready to assist the Agency to develop a more balanced and appropriate work plan. We wish to participate if at all possible.

Sincerely,

Roy E. Martin, Director
Science and Technology

Jack L. Cooper, Director
Environmental Affairs

Gustave Firtschie, Director
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FINAL REPORT TO ENVIRONMENTAL PROTECTION AGENCY

Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Waters at Dutch Harbor, Alaska

by

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1 April 1979

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DISCLAIMER

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ABSTRACT

The objective of the study reported here was to examine the marine environment in the vicinity of Dutch Harbor with emphasis on areas which had formerly, or were presently receiving seafood processing wastes. Over a period of 24 hours in June 1978, an inventory of dominant infaunal species was made together with sedimentological measurements at certain stations. Water column measurements included hydrography and nutrient chemistry. In a complementary program visible waste circulation and the *in situ* fauna was observed *via* underwater television.

A variety of coastal environments were identified in the vicinity of Dutch Harbor. North (NE and NW) of Amaknak Island is a dynamic region facing the Bering Sea and blanketed with coarse grained, well-sorted sediment. The head of Unalaska Bay (which itself appears to be relatively quiet at depth) lies immediately south of a shallow sill structure between Hog and Amaknak Islands separating it from the active region northwards. Net water movement (at least in the summer) appears to be southwards through the channel, and south of this sill the relatively carbon-rich surficial sediment is finer grained and poorly sorted. A number of stations in this latter region (between Hog and Amaknak Island) show accumulations of plant debris, and it is here that the bulk of the shellfish processing waste is currently being dumped. Because of the apparently restricted bottom circulation here, this waste material is not well dispersed and a localized patch of anoxic water was observed here.

The sea bottom at the point of discharge of processing wastes where debris is accumulating, and in areas immediately adjacent to that point, are always anaerobic and reducing environment. No infaunal or epifaunal organisms can be expected to survive such conditions, and none were observed in this study. Variable conditions exist at stations near the waste outfalls on the west side of Amaknak Island depending on their distance from outfalls, the presence or absence of plant material, their location in the channel between Hog and Amaknak Islands where water movement is reduced, and their proximity to the shallow sill between Hog and Amaknak Islands where well-mixed water is found. The interpretation of the effects of processing wastes are complicated by the presence of algal accumulations

at Stations 3D, 3H, 3AG, 3BF, and 7B (on the far side of Unalaska Bay). Stress on the benthic system on the west side of Amaknak Island must be common whenever plant (marine and terrestrial) material accumulates on the bottom. The additional input of processing wastes to such a stressed system can be expected to further alter the benthic infauna.

Processing wastes were formerly discharged directly into Dutch Harbor proper which, with Iliuliuk Bay, comprises one of the two physically restricted coastal basins. The bottom of Dutch Harbor-Iliuliuk Bay is composed of fine grain, poorly sorted sediment relatively enriched in organic carbon. The other, and much deeper, basin is the adjacent Captains Bay. At the time of year sampled (June) the spring phytoplankton bloom was apparently complete in this region and the water within the basins was well stratified and isolated from the adjacent shelf waters. Nitrate was depleted at the surface and there were strong positive gradients for, in particular, ammonia, phosphate and silica to the bottom, due to regeneration at depth and in the surface sediments. Because of the active biological consumption of oxygen and lack of advective influx of new water, dissolved oxygen concentrations at the base of the water column in Dutch Harbor proper were less than 5 ml/ℓ. However, a high oxygen consumption rate (assuming isolation of the basin water at approximately the same time of year) is not conspicuously different from that observed a decade previously, at which time the additional organic loading due to processing waste was much higher. It appears that oxygen depletion continues through the summer and that anoxic conditions occur in late summer-fall at depth, persisting until new shelf water flushes the system at some unknown period during the winter. This cycle appears to be annual and is apparently a natural consequence of local productivity and terrestrial carbon input. The infaunal composition within the Dutch Harbor-Iliuliuk Bay basin reflects a biologically stressed system. The anoxic conditions that normally occur seasonally within the basin at depth contribute to the depauperate conditions present there. However, additional stresses to this system by way of plant debris and/or processing wastes would be expected to increase the oxygen demand by the benthos and result in a further reduction of infaunal species present. It is obvious that the future deposition of processing wastes in this basin would be ecologically unsound.

A qualitative assessment of the conditions within the study area in conjunction with numerical analysis of grab data have clarified the relationship of benthic infauna to seafood processing waste discharge in the Dutch Harbor area. The numerical analysis delineated seven station groups, and 41 species groups associated with the station groups. An assessment of the relationships of station and species groups, as delineated by the numerical analysis, strengthens the qualitative assessment of each station made by television and direct observation of grab material on shipboard.

Processing wastes accumulating on the shallow shelf on the west side of Amaknak Island are responsible for severe anoxic and reducing conditions on the bottom, at the site of, and immediately adjacent to effluent piles. No benthic infaunal organisms are surviving under or close to the waste accumulations. However, the negative effects of these wastes are dissipated within relatively short distances from the accumulated deposits; i.e. healthy infaunal populations occur within a few hundred meters of these deposits. Thus, based on the very restricted areas on and around the accumulated shellfish waste piles that are affected biologically, it is apparent that existing water currents are not providing sufficient energy for adequate dispersal of wastes. Although processing wastes are not presently impacting broad areas near outfalls, accumulated wastes adjacent to Amaknak Island may eventually cover much of the nearshore bottom with serious sanitary and ecological problems to be expected.

SECTION 1
INTRODUCTION

GENERAL BACKGROUND

The oceanographic impact of effluents discharged from seafood canning operations has been only superficially examined in a few locations in Alaska. The primary impact of such activity is, as added organic waste, largely in particulate form. Since this is typically discharged into shallow coastal regions of restricted circulation, the additional oxygen demand may be such as to overload the system and create local areas of low oxygen content, anoxic sediments, and even anoxic conditions in the water column. Only certain microorganisms can exist in the absence of free oxygen, and the reduced sulfur compounds which are the primary product of marine anaerobic metabolism are generally toxic to higher organisms. Recognizing that seafood wastes may have the potential for either enriching the marine environment or for causing environmental problems, the U.S. Congress has required EPA to further investigate seafood waste discharges.

Dutch Harbor is an ideal locality for continuing research on these problems. The following are the major factors:

1) A number of processing facilities exist in a limited area as shown in Figure 1.

2) A number of morphologically distinct oceanographic environments are involved including both restricted basins and open shelf regions.

3) The waste discharge sites have been changed in recent years so that we have a region which formerly received waste, but no longer does, and a new area of recent impact.

4) The processing facilities are not presently screening to remove solids so that, in general, higher levels of degradable organic waste are discharged into the confined local waters than would be usual in other regions of the United States.

PREVIOUS WORK

EPA investigations in the Dutch Harbor area in 1975, 1976 and 1977 determined that many of the seafood outfalls were in violation of the provisions of their discharge permits. The major findings of the EPA studies

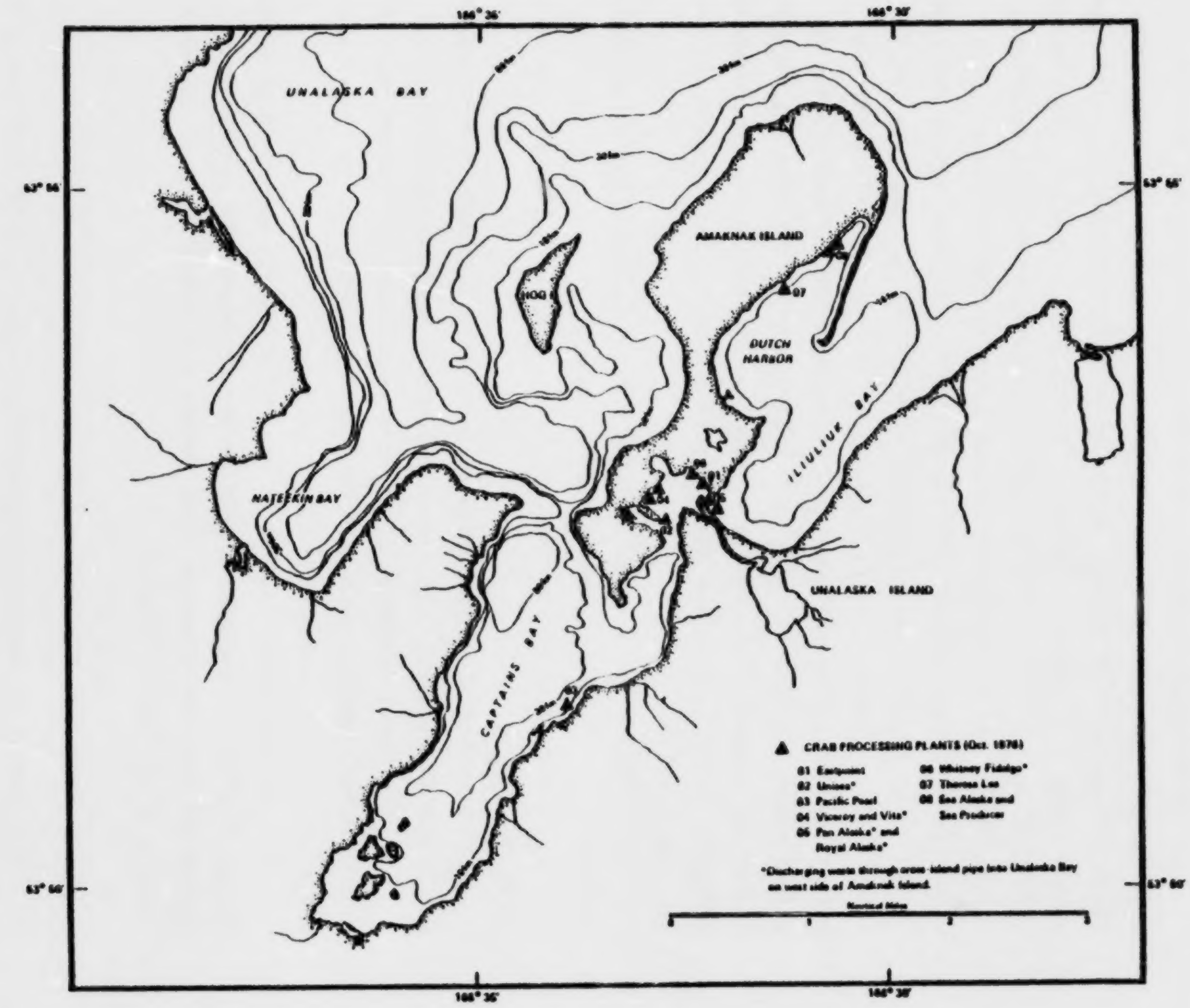
166° 35'
166° 30'
53° 55'
53° 50'
UNALASKA BAY
HOG
AMAKNAK ISLAND
DUTCH HARBOR
ILIULIUK BAY
NATEEKIN BAY
CAPTAINS BAY
UNALASKA ISLAND
01
07
30m
CRAB PROCESSING PLANTS (Oct. 1976)
01 Eastpoint
02 Unisea*
03 Pacific Pearl
04 Viceroy and Vita*
05 Pan Alaska* and Royal Alaska*
06 Whitney Fidalgo*
07 Theresa Lee
08 Sea Alaska and Sea Producer
*Discharging waste through cross-island pipe into Unalaska Bay on west side of Amaknak Island.
Nautical Mile
0
1
2
3

Figure 1. Map of Dutch Harbor and vicinity, showing location of processing plants.

were (1) water quality conditions were degraded due to seafood processing operations. Specifically, low dissolved oxygen (DO) values were found in Iliuliuk Bay, Dutch Harbor, Captain's Bay and near the old submarine repair dock. The low DO values in Captain's Bay were attributed to natural conditions, but in the other areas the primary factor was found to be the seafood wastes with the lowest DO value 0.0 mg/l near the submarine dock, (2) seafood wastes were accumulating, causing buildup of anaerobic, black, organic material. The water movement around the outfall locations was insufficient to remove the wastes, (3) benthic fauna near the outfalls consisted primarily of pollution-tolerant polychaete worms. In many of the areas examined infaunal species were smothered by the waste accumulations, and (4) H_2S concentrations greatly exceeded the 0.002 mg/l concentration reported to constitute a hazard for marine life (Stewart and Tangerone, 1977; Karna, 1978).

There have been no systematic investigations of the oceanographic consequences of the seafood disposal practices in Dutch Harbor. However, a preliminary investigation in the Dutch Harbor area by Colonell and Reeburgh (1978) determined vertical profiles for the major chemical parameters at a number of stations for two observation periods only in September and October. Current meter data were also obtained at this time to determine the major circulation patterns prevalent (at this time of year) seaward of Amaknak Island in Unalaska Bay.

The chemical data showed that, whereas the water chemistry in Unalaska Bay appeared to be "normal", the bottom waters of both Dutch Harbor and Iliuliuk Bay were anoxic at this time of year. This work is of considerable significance since:

1) It is not known whether these conditions are directly induced by the local industrial activity or are natural. Scan Bay, on the western side of Unalaska Island contains anoxic bottom waters at certain times of the year, under natural conditions.

2) In either case, this environment is well suited to an examination of the chemical gradients resulting from removal of oxygen. In particular, the distribution of NH_3-N, PO_4, and SiO_2 are of considerable interest and significance. The magnitude of such atypical nutrient contents in the water column will be a function of the length of time the water remains anoxic; Colonell and Reeburgh (*op cit*) believe that winter storms

restore oxic conditions but nothing definitive is known of this seasonality. However, even if anoxic conditions in the water column are transient, it is likely that long-term overloading of the oxidative capacity of the sediments adjacent to present or past outfalls has resulted in continuous anoxic conditions here, and nutrient profiles immediately adjacent to the sediments may possibly demonstrate a quasi steady state flux of, e.g., phosphate and ammonia from the sediments.

We are unaware of a previous quantitative investigation of the benthic fauna in the vicinity of Dutch Harbor, although benthic studies on the southeastern Bering Sea shelf are reported in Feder (1977), Feder *et al.* (1978), and Feder *et al.* (In press, a and b).

OBJECTIVE

The objective of the study was to examine the marine environment in the vicinity of Dutch Harbor with emphasis on areas which had formerly, or were presently, receiving seafood processing waste. The following activities were part of the investigation.

1) Water column hydrography and chemistry on the grid shown in Figure 2 consisting of temperature and salinity, dissolved oxygen, dissolved sulfide, and the nutrients: nitrate, nitrite, ammonia, silicate and phosphate.

2) Analysis of substrate samples at grab stations for size analysis and total organic carbon.

3) Visual observations of the sediment-water boundary using underwater television.

4) An analysis of benthic infaunal invertebrates at stations adjacent to seafood processing plants and at unpolluted sites in Dutch Harbor and vicinity.

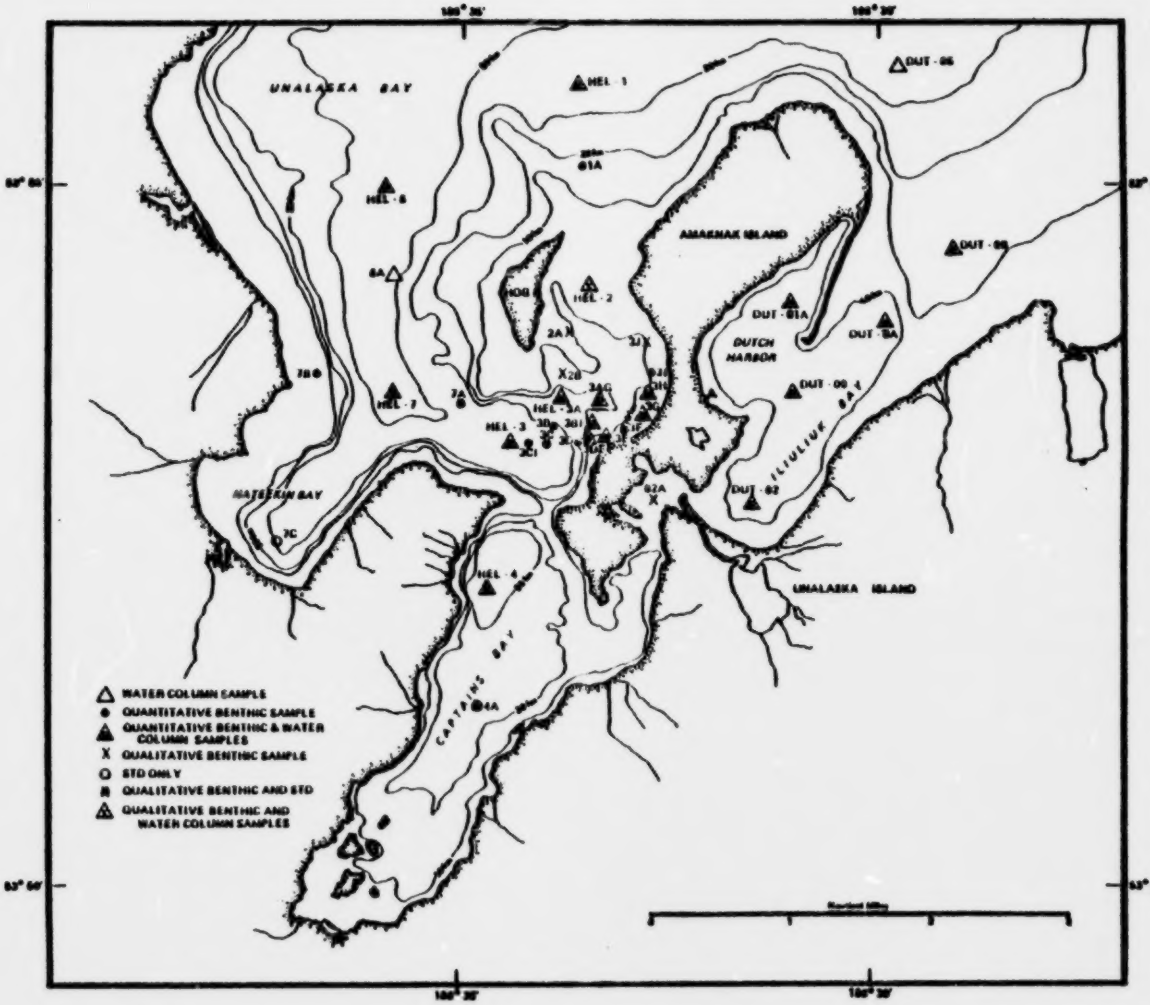
UNALASKA BAY
HEL - 1
DUT - 06
HEL - 6
AMAKNAK ISLAND
DUT - 05
6A
HEL - 2
DUT - 01A
DUT - 5A
2A
DUTCH HARBOR
X2B
3AG
HEL - 7
7B
7A
HEL - 3A
DUT - 00 - 1
HEL - 3
3Bi
2Ci
ILIULIUK BAY
02A
MATEKIN BAY
7C
DUT - 02
HEL - 4
UNALASKA ISLAND
CAPTAINS BAY
4A
WATER COLUMN SAMPLE
QUANTITATIVE BENTHIC SAMPLE
QUANTITATIVE BENTHIC & WATER COLUMN SAMPLES
QUALITATIVE BENTHIC SAMPLE
STD ONLY
QUALITATIVE BENTHIC AND STD
QUALITATIVE BENTHIC AND WATER COLUMN SAMPLES

Figure 2. Hydrographic water chemistry, sedimentological, and biological sampling grid.

SECTION 2
CONCLUSIONS

1. A variety of coastal environments occur in the vicinity of Dutch Harbor. North of Amaknak Island is a dynamic region facing the Bering Sea. The head of Unalaska Bay, immediately south of a shallow sill between Hog and Amaknak Islands, is relatively quiet at depth. Dutch Harbor proper and Iliuliuk Bay comprises one of two physically restricted coastal basins. The other, and deeper, basin is the adjacent Captain's Bay.

2. The two basins appear to be advectively isolated through the summer-early fall period. Biological activity reduces the oxygen at the bottom. In Dutch Harbor-Iliuliuk Bay, presumably because it is shallower, and this activity ultimately leads to anoxia in the Fall. This annual oxic-anoxic cycle is natural. Increased organic loading, resulting from accumulating plant debris or processing wastes, will accelerate the oxygen consumption rate and create anoxic conditions earlier in the season (and for longer periods depending on the time of renewal).

3. At the time of year sampled, the basin waters were well stratified and there were strong vertical gradients for the various nitrogen species. The relatively low N/P ratio at depth in Dutch Harbor probably indicates enhanced bottom water concentrations of phosphate as is commonly found where the underlying sediments are anoxic to, or close to, the interface.

4. The sediments in the basins are fine grained and poorly sorted, and have relatively high organic contents. Sediments north and southeast of Amaknak Island are coarser and well sorted, reflecting the dynamic environment there. The latter situation also applies to the shallow region between the islands north of Stations 2A and 2B to 3I.

5. It is probable that the sediments in regions of high organic loading are anoxic to very close to the sediment-water interface. There is an indication of an excess flux of phosphate into the base of the water column over that given by stoichiometric regeneration. This is probably due to transport in solution in association with ferrous iron.

6. Accumulations

   a. There is evidence of multi-year accumulations of processing wastes and natural plant debris on the shallow shelf on the west side of Amaknak Island. Processing wastes do not disperse very far from waste outfall sites, and are not found in the trough between Amaknak and Hog Islands.

   b. Sulfide was present in the sediment at all stations at or adjacent to processing waste outfalls and in regions of accumulation of plant debris. A black anaerobic bottom was present at all of the above stations. Total mortality of infaunal organisms occurred in these regions. Soluble sulfide was locally present in the water column at 21 and 26 m at Station 3DE. Sulfide concentration at this station increased an order of magnitude with a 5 m increase in depth.

   c. Anoxic conditions and a very reduced infauna occurred in the Dutch Harbor-Iliuliuk Bay basin, a region formerly used as a waste disposal site. These conditions are to be expected here if anoxic conditions occur in the water column on a seasonal basis.

7. Benthic Biological Conditions

   a. Benthic infaunal organisms were either smothered by the fresh processing wastes or killed by the decrease in oxygen or the severe reducing conditions within or close to waste piles.

   b. The negative effects of processing wastes on the infauna dissipated over a relatively short distance from the accumulated deposits since the weak currents present near waste outfalls are unable to transport the material far from the point of discharge.

8. Major site — specific characteristics that determine the measured effects

   a. Circulation patterns. The two basins and the trough between Hog and Amaknak Island (immediately south of a shallow sill) receive little "flushing action", and may become anoxic naturally. Hence, these areas are particularly sensitive to increased organic loading (e.g. seafood wastes and/or plant debris).

b. Outfall locations. Currently, as in the past, wastes are discharged into an area with limited circulation. The present outfall location although "open" is relatively quiescent at depth, and contributes to the problems detected in this study.

c. Amounts of waste discharged. It is apparent that processing wastes are accumulating adjacent to outfalls off Amaknak Island and that the existing water currents there do not provide sufficient energy for adequate dispersal of the wastes. Although processing wastes are not presently impacting broad areas near outfalls, it is probable that accumulated wastes adjacent to Amaknak Island will eventually cover much of the nearshore bottom. Potentially serious ecological and sanitary problems may occur here.

SECTION 3
RECOMMENDATIONS

1. Additional studies are needed to (a) determine periods and mechanisms of flushing over a seasonal cycle in the Dutch Harbor basin and the trough between Amaknak and Hog Islands, (b) determine water column and longshore primary productivity, and terrestrial carbon input to the shallow marine system in the Dutch Harbor area to permit computation of a carbon-oxygen consumption mass balance, and (c) examine basin sediments in the context of overlying cycling oxic/anoxic water.

2. Development of a seasonal annual program designed to monitor the marine systems adjacent to processing waste outfalls is essential.

3. Current seafood waste disposal practices should be improved so that gross solids are either removed or dispersed by discharging effluent into areas of well-mixed waters. Further study of potential disposal sites will be needed to ensure that processing wastes are not flushed back into less dynamic waters where they will accumulate, e.g. the trough between Hog and Amaknak Islands, and the Dutch Harbor-Iliuliuk Bay basin.

SECTION 4
METHODS

SAMPLING

The station grids shown in Figures 2, 3 and 4 were sampled onboard the R/V *Acona*, 11-12 June 1978. Station descriptive data are included in Table 1.

Water samples for salinity, dissolved oxygen and nutrients were collected using Go-flo Niskin bottles at the stations listed in Table 1.

Splits from the van Veen grabs were taken for size analysis and carbon analysis.

HYDROGRAPHY

Temperature and salinity were obtained *via* STD with discrete Nansen bottle calibrations.

The Institute of Marine Science employs a Plessey Enviromental Systems 9040 STD system (S.N. 5341) for vertical profiling of temperature and salinity. During a cast, S, T, and D are sampled five times per second and are recorded digitally on magnetic tape and on analog chart paper. The analog trace is for backup and field use; the magnetic tape is processed to yield high quality data.

The STD system is capable of high precision but relatively less accuracy unless field corrected using Nansen bottles for discrete samples. When thusly corrected, the accuracy is dependent on standard techniques for determining temperature and salinity. The generally accepted accuracy for temperature using deep sea reversing thermometer is within ± 0.02°C and that for salinity using a bench salinometer is within ± 0.02‰.

The STD system is recalibrated every two years against standards traceable to NBS (National Bureau of Standards). Field corrections are determined separately for each cruise based on discrete samples. Thermometers are calibrated at least every two years and the bench salinometers are calibrated on an irregular basis. Records of field corrections are kept to monitor STD function.

DISSOLVED OXYGEN ANALYSIS

The dissolved oxygen contents of discrete water samples are determined using the Chesapeake Bay Institution microburet modification of the Winkler

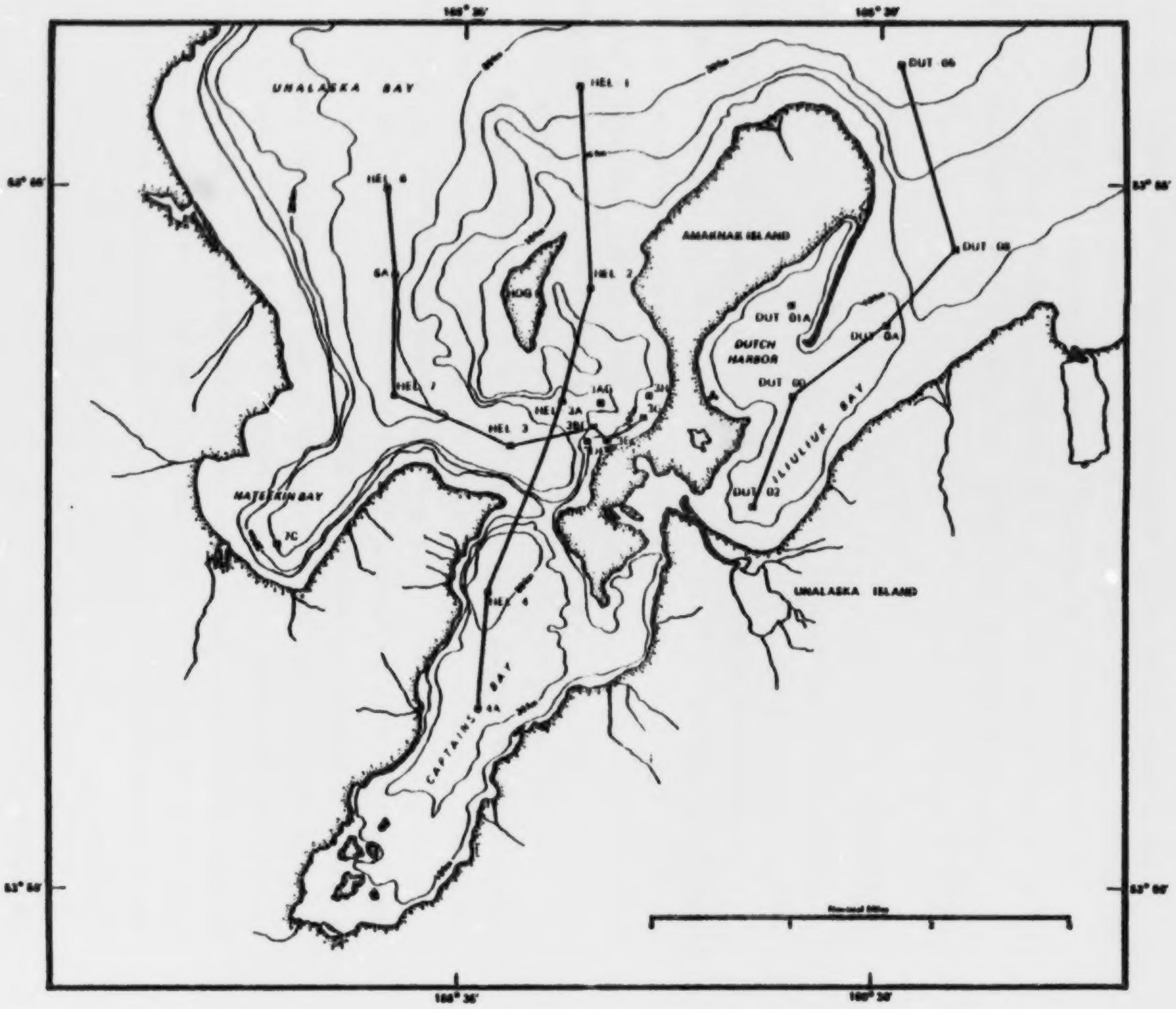
166° 35'
166° 30'
53° 55'
53° 50'
UNALASKA BAY
HEL 1
HEL 2
HEL 6
6A
HEL 7
HEL 3
HEL 3A
3B
1AG
3C
3EA
HEL 4
4A
HOG
NATEEKIN BAY
7C
CAPTAINS BAY
AMAKNAK ISLAND
DUTCH HARBOR
DUT 01A
DUT 0A
DUT 00
DUT 02
DUT 06
DUT 08
ILIULIUK BAY
UNALASKA ISLAND

Figure 3. Stations occupied for hydrographic measurements.

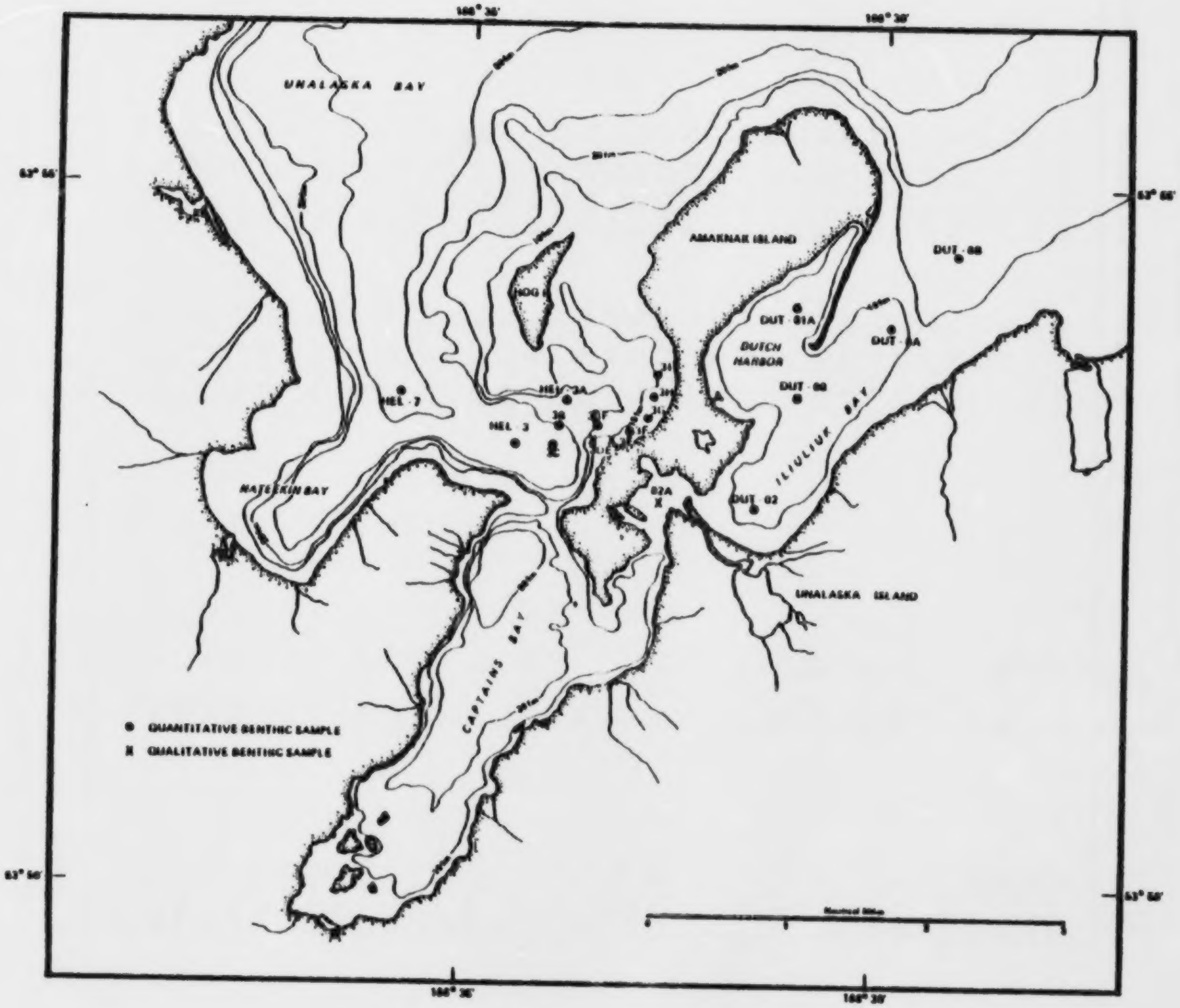
UNALASKA BAY
AMAKNAK ISLAND
HOG I
DUTCH HARBOR
ILIULIUK BAY
UNALASKA ISLAND
NATEEKIN BAY
CAPTAINS BAY
HEL - 7
HEL - 3
HEL - 3A
DUT - 01A
DUT - 08
DUT - 02
DUT - 06
02A
● QUANTITATIVE BENTHIC SAMPLE
X QUALITATIVE BENTHIC SAMPLE

Figure 4. Biological stations with taxonomic data based on laboratory analysis. Stations used in cluster analysis.

TABLE 1. STATION DATA FOR CRUISE OF R/V *ACONA*, 11-12 JUNE 1978 IN THE VICINITY OF DUTCH HARBOR, ALASKA. HYDROGRAPHIC, WATER CHEMISTRY, SEDIMENTOLOGICAL AND BIOLOGICAL STATIONS. HC = HYDROGRAPHIC AND CHEMISTRY STATION; B = BIOLOGICAL STATION; S = SEDIMENTOLOGICAL

Station Name	Ship Operation	Latitude	Longitude	Depth (m)
DUT-01A	HC, B[1]	53°55.2'	166°31.15'	28
DUT-02	HC, B[1]	53°52.8'	166°31.2'	30
DUT-00	HC, B[1]	53°53.5'	166°30.8'	34
DUT-05	HC	55°55.7'	166°29.97'	55
HEL-1	HC, B	53°56.0'	166°34.0'	80
1A	B, S	53°55.3'	166°33.7'	46
HEL-2	HC, B	53°54.6'	166°33.5'	15
3E	HC, B, S	53°52.55'	166°33.45'	16
3F	B[1]	53°53.2'	166°33.65'	51
3G	HC, B[1], S	53°53.18'	166°33.3'	31
3H	HC, B[1], S	53°53.72'	166°32.5'	34
3I	B[1], S	53°53.94'	166°32.95'	32
3J	B	53°54.33'	166°33.6'	14
2A	B	53°54.25'	166°33.3'	14
2B	B	53°53.87'	166°33.36'	14
HEL-3A	HC, B[1], S	53°53.5'	166°33.21'	40
3B	B[1], S	53°53.35'	166°34.0'	51
3D	B	53°52.95'	166°33.7'	57
3C	B[1]	53°53.04'	166°33.9'	68
3C1	B, S	53°53.1'	166°34.1'	48
HEL-3	HC, B[1], S	53°53.2'	166°34.25'	49
7A	B	53°53.4'	166°35.1'	80
HEL-7	HC, B[1]	53°53.6'	166°35.8'	98
7B	B	53°53.8'	166°36.6'	51
7C	HC	53°52.6'	166°37.15'	62
6A	HC	53°54.45'	166°35.97'	117
HEL-6	HC, B, S	53°55.2'	166°35.9'	132
02A	B,S	53°52.65'	166°32.65'	28
DUT-0A	HC, B[1], S	53°54.1'	166°29.18'	29
DUT-0B	HC, B[1], S	53°54.44'	166°28.97'	22
HEL-1	HC, B	53°56.0'	166°34.0'	76
3AG	HC, B, S	53°53.44'	166°33.32'	38
3BF	HC, B[1], S	53°53.27'	166°33.4'	58
3DE	HC, B, S	53°52.9'	166°33.4'	26
HEL-4	HC, B	53°52.2'	166°34.4'	95
4A	HC, B	53°51.3'	166°34.97'	78

[1] Station for which biological data available for the cluster analysis included in this report.

titration (Carpenter, 1965). Samples are drawn from the Nansen bottles into calibrated BOD-type bottles in the usual fashion. One ml each of 3M $MnCl_2$ and the Na OH/Na I (8M and 4M respectively) are added to preserve the oxygen contents. Analysis consists of acidification with 10N H_2SO_4 and titration against 0.2M sodium thiosulfate using a Gilmont micropipet-buret. Standardization is against KIO_3. The precision of this method is about ± 0.05 ml O_2/ℓ (see discussion by Carritt and Carpenter, 1966).

NUTRIENT ANALYSIS

Nutrients are determined using Technicon®[1] Autoanalyzer® procedures based on the manual methods of Murphy and Riley (1962) for reactive phosphorus and Armstrong *et al.* (1967) for dissolved silicon, nitrite. Ammonia is measured by the pheno-hypochlorite method of Koroleff (1970), as adapted by Slawyk and MacIsaac (1972).

Ammonia: Ammonia is determined by the Berthelot reaction in which hypochlorous acid and phenol react with ammonia in aqueous alkaline solution to form indophenol blue, an intensely blue chromophore with an absorption maximum at 537 nm.

Orthosilic Acid: Orthosilic acid is determined by its reaction with molybolate in aqueous acidic solution to form silicomolybdic acid. In this procedure stannous chloride is used to reduce silicomolybdite acid to the heteropoly acid which has an absorption maximum at 820 nm.

Nitrate, Nitrite, Nitrite: Nitrite is determined by the Greiss reaction in which sulfanilamide and N-(1-naphthyl) ethylenidiamine dihydrochloride (NNED) reacts with nitrite in aqueous acidic solution to form an intensely pink diazo dye with an absorption maximum at 570 nm. Nitrate, after it is reduced to nitrite by passage through a column containing copperized cadmium filings, is determined in an identical manner. Thus, the sum of nitrate plus nitrite is determined in the nitrate procedure.

Orthophosphate: Phosphate is determined as phosphomolybdic acid which in its reduced form in the presence of antimony has an absorption maximum at $\simeq$ 880 nm.

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[1] Copyright notation

SULFIDE

Soluble water column sulfide was determined by the method described by Strickland and Parsons (1968) as modified by Cline (1969). This involves formation of methylene blue from dimethyl p-phenylene diamine and is an application to marine water of a well established colorimetric procedure.

SEDIMENT TOTAL ORGANIC CARBON

Sediment samples for total organic carbon analysis were collected by van Veen Grab and frozen shipboard. In the laboratory aliquots were freeze-dried, rough weighed to approximately 2 g and treated with 1N HCl for four hours in a water bath at 60°C to destroy inorganic carbonate. After filtering through a 0.45 µm glass fiber filter (Gelman AE®), the mud was dried at 60°C overnight. Triplicate samples were then weighed into crucibles along with metal accelerators and analyzed in a Leco® carbon analyser. The instrument was calibrated with high and low carbon standards as prescribed by the furnace manufacturers. (High: 0.892 %c/g; low: 0.062 %c/g). The data included in this report are, unfortunately, still preliminary and subject to revision.

SEDIMENT SIZE ANALYSIS

Two complementary techniques have been used for the sediment grain size analysis. The size fraction larger than 4 ϕ (62.5 µm) was dried and passed through a battery of sieves of decreasing 0.5 ϕ mesh using a Ro-tap® shaker. After shaking the sediment on each screen was transferred to pre-weighed beakers for determination of the amount of material in each size class.

The less than 4 ϕ fraction was transferred to 1 ℓ volumetric cylinders in a 27°C water bath. Aliquots were extracted by pipette at different times and depths according to standard technique based on Stokes Law assuming a density of 2.65 in this case Calgon® (2.5 g/ℓ) was used as a dispersant to present flocculation.

The above general analytical scheme was prefaced by a peroxide treatment to destroy organic matter. This particular batch of samples--particularly those from adjacent to the cannery outfalls--contained large amounts of fish remains in addition to native organic material so that a 50% H_2O_2 digestive solution was employed and treatment was continued for several days. Samples from near the outfall sites also contained very large amounts of refractory biogenic material: crustacean carapaces, fish bones, etc. Because this material would have severely biased the sediment size spectrum analysis it was resolved to arbitrarily discard all material which did not pass a 1 mm (0 ϕ) screen. This unusual procedural modification must be borne in mind if these data should be compared with those from elsewhere.

Size class data were plotted in the normal way to give cumulative curves and the statistical parameters computed according to the methods of Folk (1968). Representative curves are given in Figure 5.

BENTHIC BIOLOGICAL SAMPLES

A van Veen grab was used to take five replicate samples at each station selected. At several stations only 1-2 replicates were taken. Samples were washed on a 1.0 mm mesh screen, fixed in 10% buffered formalin and subsequently examined at the Marine Sorting Center, Institute of Marine Science, Seward.

NUMERICAL ANALYSIS

Site groups and species assemblages were identified using cluster analysis. Stations used in the analysis are presented in Figure 4. Cluster analysis can be divided into three basic steps.

1. Calculation of a measure of similarity or dissimilarity between entities to be classified.
2. Sorting through a matrix of similarity coefficients to arrange the entities in a hierarchy or dendrogram.
3. Recognition of classes within the hierarchy.

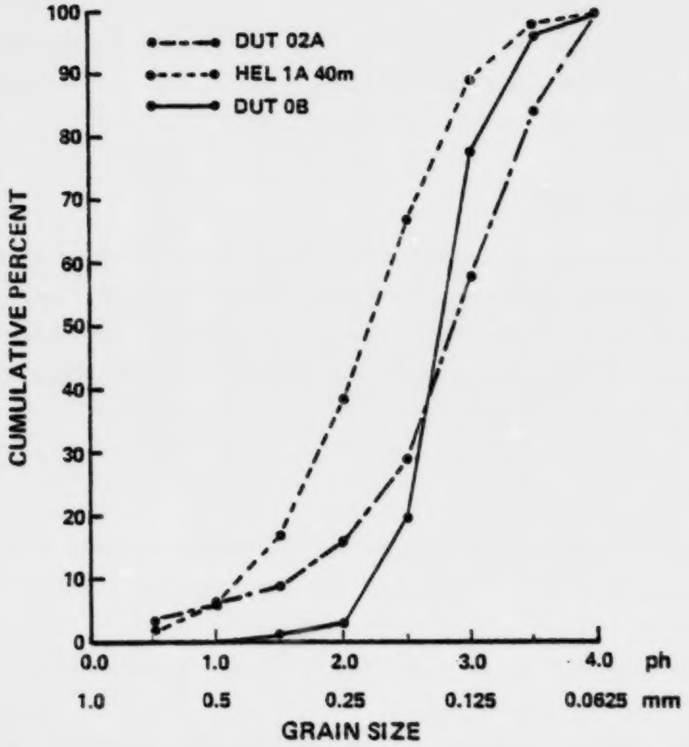

Figure 5. Grain size analysis for sediments from three stations in the Dutch Harbor area.

Data reduction prior to calculation of similarity coefficients consisted of elimination of taxa that could not be identified to genus and taxa that occurred at a single station in low numbers.

The coefficient used to calculate similarity matrices for cluster analysis routines was the Czekanowski coefficient[1]

Czekanowski Coefficient

$Cs_{1,2} = \frac{2W}{A + B}$ where A = the sum of the measures of attributes of entity one

B = the sum of the measures of attributes of entity two

W = the sum of the lesser measures of attributes shared by entities one and two.

The Czekanowski coefficient has been used effectively in marine benthic studies by Field and MacFarlane (1968), Field (1969, 1970 and 1971), Day *et al.* (1971), Stephenson and Williams (1971), and Stephenson *et al.* (1972). This coefficient emphasizes the effect of dominant species on the classification, and is often used with some form of transformation. The Czekanowski coefficient was used to calculate similarity matrices for normal cluster analysis (with sites as the entities to be classified and species as their attributes) and inverse cluster analysis (with species as entities and sites as attributes) using both untransformed and natural logarithm transformed abundance data (individuals/m^2). The natural logarithm transformation, $Y = ln(X+1)$, reduces the influence that dominant species have on the similarity determination.

Dendrograms were constructed from the similarity matrices using a group-average agglomerative hierarchical cluster analysis (Lance and Williams, 1966). An an aid in the interpretation of dendrograms formed by cluster analyses, two-way coincidence tables comparing site groups formed by normal analysis and species groups formed by inverse analysis were constructed (Stephenson *et al.*, 1972). In each table the original species x sites data matrix was rearranged (based on the results of both normal and inverse analysis) so that the sites or species with the highest similarities were adjacent to each other.

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[1] The Czekanowski coefficient is synonymous with the Motyka (Mueller-Dombois and Ellenberg, 1974), and Bray-Curtis (Clifford and Stephenson, 1975) coefficients.

DIVERSITY

Species diversity can be thought of as a measurable attribute of a collection or a natural assemblage of species, and consists of two components: the number of species or "species richness" and the relative abundance of each species or "evenness". The two most widely used measures of diversity which include species richness and evenness are the Brillouin (1962) and Shannon (Shannon and Weaver, 1963) information measures of diversity (Nybakken, 1978). There is still disagreement on the applicability of these indices, and the results are often difficult to interpret (Sager and Hasler, 1969; Hurlbert, 1971; Fager, 1972; Peet, 1974; Pielou, 1966a, b). Pielou (1966a,b, 1977) has outlined some of the conditions under which these indices are appropriate.

The Shannon Function

$$H' = -\sum_i p_i \log p_i \text{ where } p_i = \frac{n_i}{N}$$

where n_i = number of individuals in the i^{th} species

N = total number of individuals

assumes that a random sample has been taken from an infinitely large population whereas the Brillouin function

$$H = \frac{1}{N} \log \frac{N!}{n_1!n_2!\cdots n_s!}$$

is appropriate only if the entire population has been sampled. Thus, if we wish to estimate the diversity of the fauna at a sampling site the Shannon function is appropriate. The Brillouin function is merely a measure of the diversity of the five grab samples taken at each site, and makes no predictions about the diversity of the benthic community that the samples were drawn from. The evenness of samples taken at each site can be calculated using the Brillouin measure of evenness, $J = H/H_{maximum}$, where H = Brillouin diversity function. $H_{maximum}$, the maximum possible diversity for a given number of species, occurs if all species are equally common and is calculated as:

$$H_{maximum} = \frac{1}{N} \log \frac{N!}{\{[N/s]!\}^{s-r}\{([N/s]+1)!\}^{r}}$$

where $[N/s]$ = the integer part of N/s
s = number of species in the censused community
$r = N - s[N/s]$

Theoretically the evenness component of the Shannon function can be calculated from the following:

$$J' = \frac{H'}{\log s^*}$$

where H' = Shannon diversity function
s^* = the total number of species in the randomly sampled community

However, s* is seldom known for benthic infaunal communities. Therefore, the evenness component of the Shannon diversity index was not calculated (for a discussion see Pielou, 1977). Both the Shannon and Brillouin diversity indices were calculated in the present study (see discussions in Loya, 1972 and Nybakken, 1978). Species richness (Margalef, 1958) was calculated as

$$SR = \frac{(S-1)}{ln\ N}$$

where S = the number of species
N = the total number of individuals

The Simpson index (Simpson, 1949) was also calculated to enable comparison of the dominance structure.

TROPHIC STRUCTURE

The feeding method used by each of the common species collected was recorded. Species were classified into 5 feeding classes: suspension feeders (SF), deposit feeders (DF), predators (P), scavengers (S) and other (O). All species utilized for the determination of trophic structure were assigned to feeding classes based on the literature (MacGinitie and MacGinitie, 1949; Morton, 1958; Fretter and Graham, 1962; Jørgensen, 1974; Barnes, 1974; Trueman, 1975; Yonge and Thompson, 1976; Jumars and Fauchald, 1977; Feder and Matheke, in press) and personal observations. Since species are distributed along a continuum of feeding types and many organisms utilize several feeding modes, it is often difficult to place a species in a specific class. For example, protobranch molluscs, generally regarded as deposit feeders, may also utilize particles in suspension (Stasek, 1965; Stanley, 1970). However, since these molluscs probably obtain most of their nutritional requirements from the sediment, we classified them as deposit feeders. It is even more difficult to make a distinction between scavengers and deposit feeders, as for example, some of the larger polychaetes and amphipods that can ingest larger food particles as well as small detrital fragments. If these organisms were motile, and able to operate efficiently as scavengers, as well as incorporate sediment in their diet, they were classified as both scavengers and deposit feeders. Species whose feeding behavior was unknown, or uncertain, were classified as "other". The percentage of individuals belonging to each feeding classification was calculated for each site group. Where a species was assigned to two feeding classes we arbitrarily assigned one half of the individuals of that species to each class. Species were also classified into three classes of motility: sessile, discretely motile (generally sessile but capable of movement to escape unfavorable environmental conditions), and motile (after Jumars and Fauchald, 1977). The percentage of individuals belonging to each motility class was also calculated for each station group.

SECTION 5

HYDROGRAPHY, WATER CHEMISTRY AND SEDIMENTOLOGY

INTRODUCTION

In this section we consider the hydrography, and limited aspects of the marine chemistry and sedimentology of the region shown in Figure 1. The principal physiographic features here are: an indentation (Unalaska Bay) of the Bering Sea shelf; two shallow and physically isolated basins (Captains Bay and the combined Dutch Harbor-Iliuliuk Bay area, hereafter simply referred to as "Dutch Harbor"); and a shallow channel between Hog and Amaknak Islands. This area borders the southern Bering Sea. Colonell and Reeburgh (1978) have discussed the summer wind regime here which appears to be of major importance to local water movements. This is noted further briefly below.

The overall objective of this section of the project has been to describe oceanographic conditions with particular reference to those areas which were the major disposal sites of seafood processing wastes (mainly Dutch Harbor), and the region on the west coast of Amaknak Island where most of the processing material is currently discharged.

Alaska has countless examples of semi-restricted bodies of coastal and estuarine water - fjords, lagoons etc. - that have been seasonally well studied. In general, because of physical restrictions on the force exchange of water, the bottom waters in these environments become oxygen deficient at certain times of the year. Whether true anoxic conditions occur within the water column depends, however, on localized characteristics such as the geometry of the basin, the below surface depth of the confining barrier, and the seasonal density of the source water. In the fjords of south central and southeast Alaska, all the inlets studied to date flush at least annually (Heggie and Burrell, 1977). By way of contrast certain Aleutian bays do go anoxic in the summer: Scan Bay - a neighbor of Dutch Harbor - is the best studied to date (Hattori *et al.*, 1978). Unalaska Bay and the region west of Amaknak Island have relatively unrestricted access to the Bering Sea, and this precludes anything other than strictly local oxygen deficiency.

Two immediate problems associated with this project appeared to be whether Dutch Harbor proper (and possibly also Captains Bay) might naturally go anoxic at certain times of the year. Clearly, enhanced anthropogenic organic loading within Dutch Harbor would exacerbate any such tendency but might not, *per se*, be the direct cause of bottom water anoxia. Secondly, what was the oceanographic regime in the Hog-Amaknak Island channel in relation to the existing and projected rate of industrial perturbation there.

Oceanographic conditions here are strongly seasonal. If, for example, a regular pattern of stagnation were to occur in the basins, flushing would be a function of the annual regional meteorological conditions. A detailed description and understanding of this would then require year-round, and probably, multi-year observation, and this has not been possible to date.

RESULTS

We have obtained data for two days during June (1978) only. Some comparison may be made with the June 1977 data of Brickell and Goering (1970) and the October (1977) data of Colonell and Reeburgh (1978). However considerable additional data at other times of the year are an urgent need.

Hydrographic measurements were taken at the stations shown in Figures 2 and 3, and listed in Table 1. These data are tabulated, and vertical profiles are plotted, in Figures 6-29. Grain size data from stations DUT-02A, DUT-0B, and HEL-1 are included in Figure 5. To better illustrate the hydrography in this region, horizontal profiles for temperature, salinity and density along the tract lines shown in Figure 3 are presented as Figures 30-32. The upper profile, from stations HEL-6 to 3G, is illustrative of open shelf conditions up to the near shore region adjacent to the present site of maximum processing waste dumping. (It should be noted that the slight basin structure shown is an artifact related to the curvation of the profile line; these are not closed basins as in the two lower profiles.) The center profile is again from the open shelf across the shallow region between Amaknak and Hog Islands, over the sill into Captains Bay. The lower profile is basically Dutch Harbor proper and the shelf seaward of this. Short-term temperature and salinity changes at stations HEL-1 and DUT-00 are included in Figure 33.

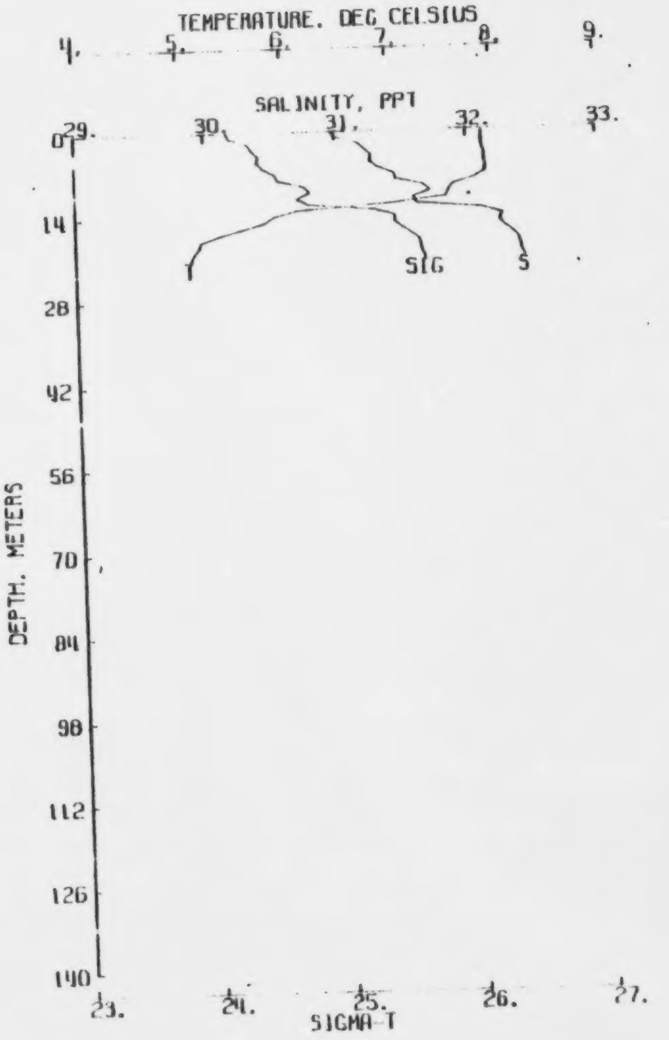
Dissolved oxygen and nutrient data for the water column are listed in Tables 2-12. Figures 34-40 show profiles (along the same lines discussed

---

*Note: Continuation of text on page 70

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  55.   DUT001A   11/ 6/78
---------------------------                              10.0 HOURS GMT

 LATITUDE = 51  55.2N   LONGITUDE = 166  31.2W   SONIC DEPTH =   28 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- ( ) ---NOT RECORDED
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
-------------------------------------------------------------
I          DIRECTION         SPEED                           I
I WIND     185 - 194 DEGR     5 KNOTS                        I
-------------------------------------------------------------
I          DIRECTION         HEIGHT      PERIOD              I
I SEA        0 -   0 DEGR       M.          SECS             I
I SWELL        -     DEGR       M.          SECS             I
-------------------------------------------------------------
I TEMPERATURES -DRY =  10.0 DEGR C.   BAROMETRIC PR. =1019.8 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M  I
-------------------------------------------------------------

      DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
      METERS        DEG C          PPT                      DYN M
        0.          7.90         30.962        24.17        0.
        1.0         7.96         30.998        24.19        0.004
        5.0         7.94         31.272        24.40        0.018
       10.0         7.59         31.724        24.81        0.035
       15.0         5.81         32.251        25.45        0.050
       20.0         5.13         32.421        25.66        0.062
```

Figure 6. Hydrography and vertical profiles: DUT-01A.



CRUISE   261   STATION   55

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  56.    DUT002     11/ 6/78
---------------------------                              11.6 HOURS GMT

 LATITUDE = 53  52.8N   LONGITUDE = 166  31.2W   SONIC DEPTH =   30 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- ( ) ---NOT RECORDED        .
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
-------------------------------------------------------------------
I         DIRECTION         SPEED                                 I
I WIND    175 - 194 DEGR     5 KNOTS                              I
-------------------------------------------------------------------
I         DIRECTION        HEIGHT      PERIOD                     I
I SEA       0 -   0 DEGR      4.         SECS                     I
I SWELL       -     DEGR      0.         SECS                     I
-------------------------------------------------------------------
I TEMPERATURES -DRY =   9.4 DEGR C.   BAROMETRIC PR. =1019.2 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M  I
-------------------------------------------------------------------

        DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C          PPT                       DYN M
          0.          7.93         30.516        23.81        0.
          1.0         7.92         30.357        23.69        0.004
          5.0         7.72         31.347        24.52        0.020
         10.0         7.24         31.762        24.88        0.036
         15.0         6.03         32.306        25.46        0.050
         20.0         5.22         32.391        25.63        0.062
         25.0         4.92         32.461        25.71        0.074
```

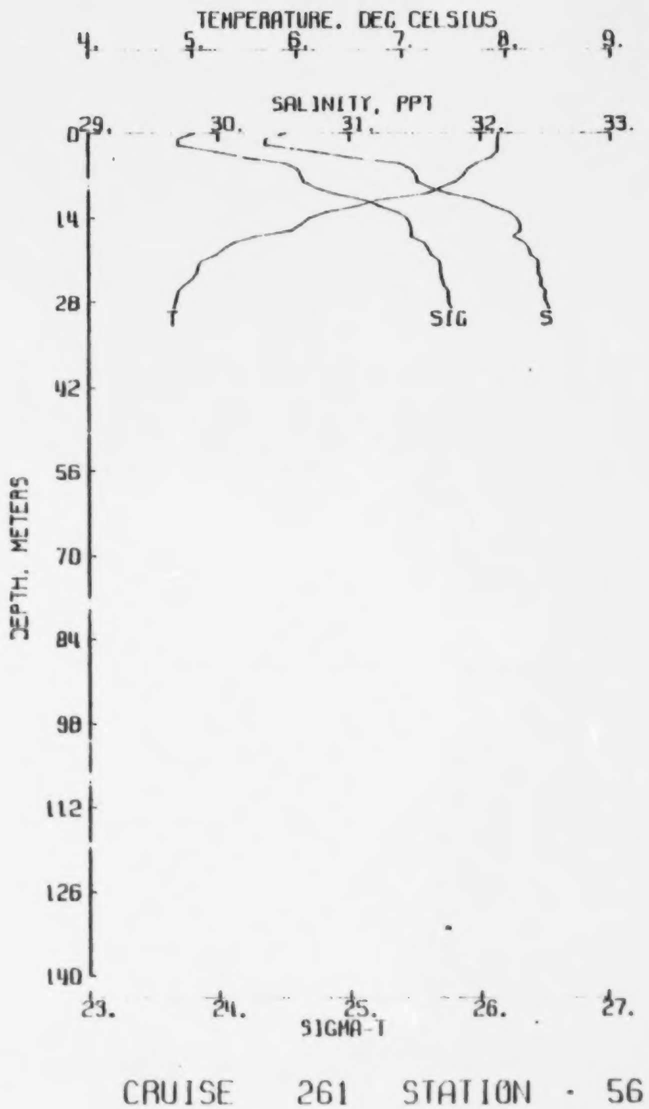


Figure 7. Hydrography and vertical profiles: DUT-02.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  57.   DUT000     11/ 6/78
----------------------------                               13.0 HOURS GMT

  LATITUDE = 53  53.5N   LONGITUDE = 166  30.8W   SONIC DEPTH =   34 M

  1-DIGIT WEATHER CODE IS (X?) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- ( ) ---NOT RECORDED        .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
--------------------------------------------------------------------
I           DIRECTION          SPEED                                I
I WIND      185 - 194 DEGR     10 KNOTS                             I
--------------------------------------------------------------------
I           DIRECTION        HEIGHT      PERIOD                     I
I SEA        0 -    0 DEGR      M.          SECS                    I
I SWELL          -    DEGR      M.          SECS                    I
--------------------------------------------------------------------
I TEMPERATURES -DRY =    7.2 DEGR C.   BAROMETRIC PR. =1018.3 MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =        M  I
--------------------------------------------------------------------

        DEPTH       TEMPERATURE   SALINITY      SIGMA-T      DELTA-D
        METERS        DEG C         PPT                       DYN M
          0.          7.75        30.763        24.03        0.
          1.0         7.73        30.814        24.07        0.004
          5.0         7.63        31.211        24.40        0.019
         10.0         6.73        32.011        25.14        0.035
         15.0         6.10        32.265        25.42        0.049
         20.0         5.42        32.161        25.42        0.061
         25.0         4.97        32.468        25.71        0.073
```

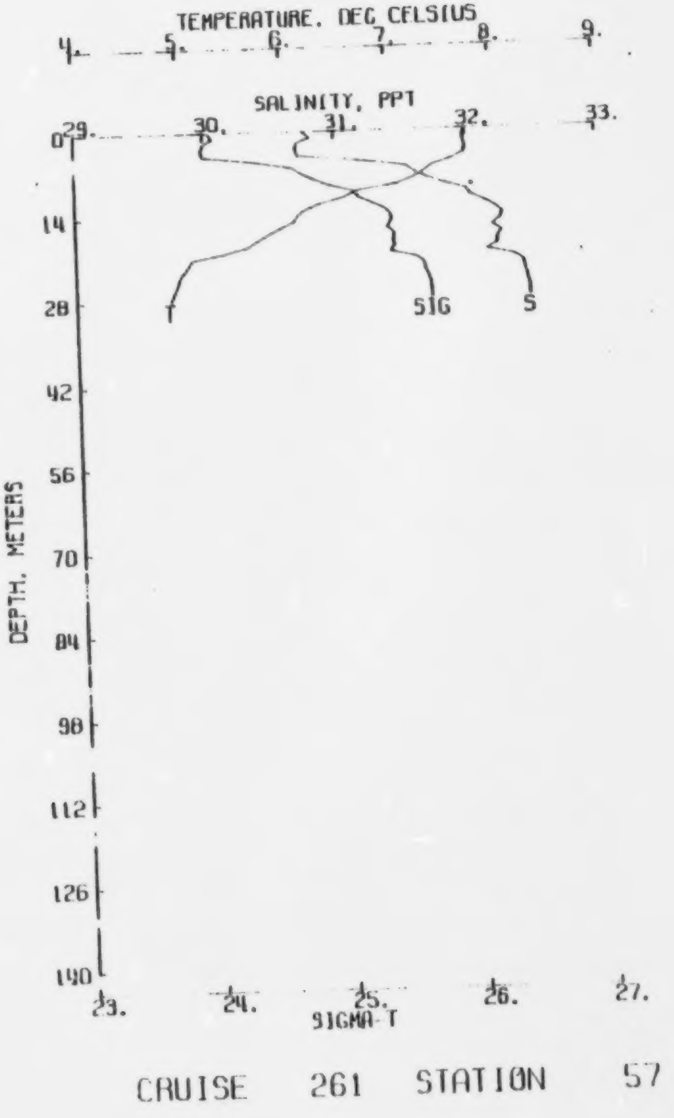


Figure 8. Hydrography and vertical profiles: DUT-00.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  58.   DUT005      11/ 6/78
-=------------------------                                  14.7 HOURS GMT

 LATITUDE = 55  55.7N   LONGITUDE = 166  30.0W   SONIC DEPTH =   55 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (7) ---7/8
 VISIBILITY --- (7) ---10-20 KM
-----------------------------------------------------------------------
I          DIRECTION          SPEED                                  I
I WIND     115 - 124 DEGR      7 KNOTS                               I
-----------------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                     I
I SEA      115 - 124 DEGR   0.2 M.           SECS                    I
I SWELL         -    DEGR      9.           SECS                     I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =    9.3 DEGR C.   BAROMETRIC PR. =1017.3 MB     I
I              -WET =        DEGR C.   TRANSPARENCY   =         M    I
-----------------------------------------------------------------------

        DEPTH      TEMPERATURE     SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C           PPT                       DYN M
          0.          7.23          31.636        24.79        0.
          1.0         7.23          31.636        24.79        0.003
          5.0         6.35          32.215        25.35        0.015
         10.0         6.29          32.238        25.38        0.028
         15.0         6.24          32.263        25.40        0.041
         20.0         6.22          32.273        25.42        0.054
         25.0         6.18          32.292        25.43        0.067
         30.0         6.18          32.293        25.44        0.080
         35.0         5.95          32.331        25.49        0.093
         40.0         5.88          32.339        25.51        0.105
         45.0         5.76          32.379        25.55        0.118
         50.0         5.61          32.402        25.59        0.130
```

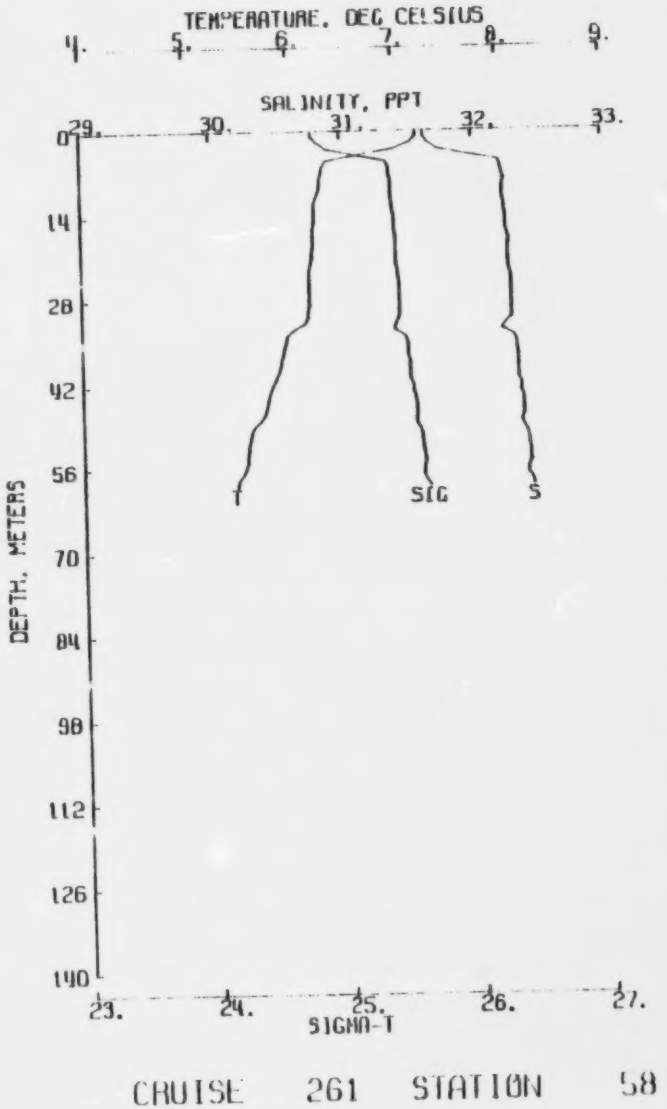


Figure 9. Hydrography and vertical profiles: DUT-05.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  59.   HEL001     11/ 6/78
-------------------------------                           15.0 HOURS GMT

 LATITUDE = 51  56.0N   LONGITUDE = 166  34.0W   SONIC DEPTH =   80 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (7) ---7/8
 VISIBILITY --- (7) ---10-20 KM
---------------------------------------------------------------------
I          DIRECTION         SPEED                                  I
I WIND     175 - 184 DEGR    10 KNOTS                               I
---------------------------------------------------------------------
I          DIRECTION          HEIGHT       PERIOD                   I
I SEA      175 - 184 DEGR    0.5 M.          SECS                   I
I SWELL      -       DEGR        M.          SECS                   I
---------------------------------------------------------------------
I TEMPERATURES -DRY =    7.8 DEGR C.   BAROMETRIC PR. =1017.1 MB    I
I              -WET =        DEGR C.   TRANSPARENCY   =       M     I
---------------------------------------------------------------------
```

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	6.74	31.128	24.45	0.
1.0	6.74	31.128	24.45	0.003
5.0	6.43	32.208	25.34	0.015
10.0	6.42	32.226	25.35	0.028
15.0	6.34	32.209	25.35	0.041
20.0	6.23	32.246	25.39	0.054
25.0	6.11	32.298	25.45	0.067
30.0	6.03	32.310	25.47	0.080
35.0	5.97	32.311	25.48	0.093
40.0	5.85	32.329	25.50	0.105
45.0	5.62	32.366	25.56	0.117
50.0	5.42	32.373	25.59	0.130
60.0	5.17	32.548	25.75	0.153
70.0	5.07	32.571	25.78	0.175

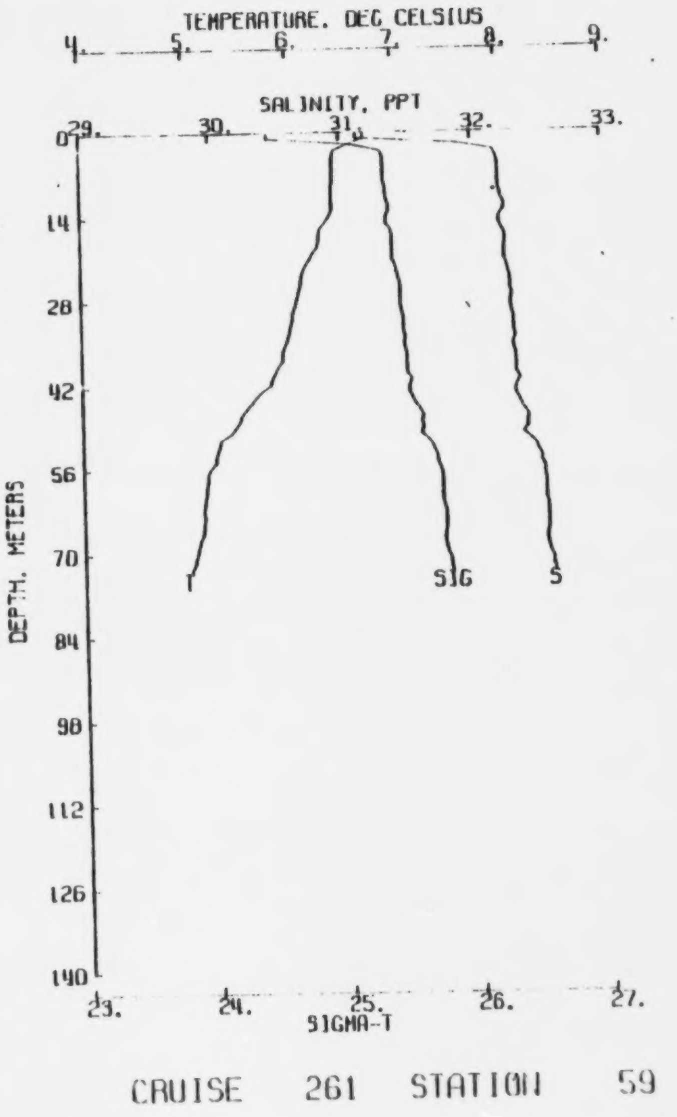


Figure 10. Hydrography and vertical profiles: HEL-1.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  60.   HEL002     11/ 6/78
---------------------------                               17.7 HOURS GMT

  LATITUDE = 53  54.6N   LONGITUDE = 166  33.5W   SONIC DEPTH =   14 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (6) ---STRATOCUMULUS      .
  CLOUD AMOUNT --- (3) ---3/8 TOTAL    .
  VISIBILITY --- (7) ---10-20 KM
----------------------------------------------------------------
I         DIRECTION        SPEED                                I
I WIND    165 - 174 DEGR   15 KNOTS                             I
----------------------------------------------------------------
I         DIRECTION        HEIGHT      PERIOD                   I
I SEA     165 - 174 DEGR  0.3 M.          SECS                  I
I SWELL       -     DEGR      M.          SECS                  I
----------------------------------------------------------------
I TEMPERATURES -DRY =   7.8 DEGR C.   BAROMETRIC PR. =1015.6 MB I
I              -WET =       DEGR C.   TRANSPARENCY   =       M  I
----------------------------------------------------------------

        DEPTH      TEMPERATURE   SALINITY     SIGMA-T      DELTA-D
        METERS       DEG C         PPT                      DYN M
          0.          7.40        29.837       23.35        0.
          1.0         7.40        29.837       23.35        0.005
          5.0         7.37        30.850       24.15        0.022
```

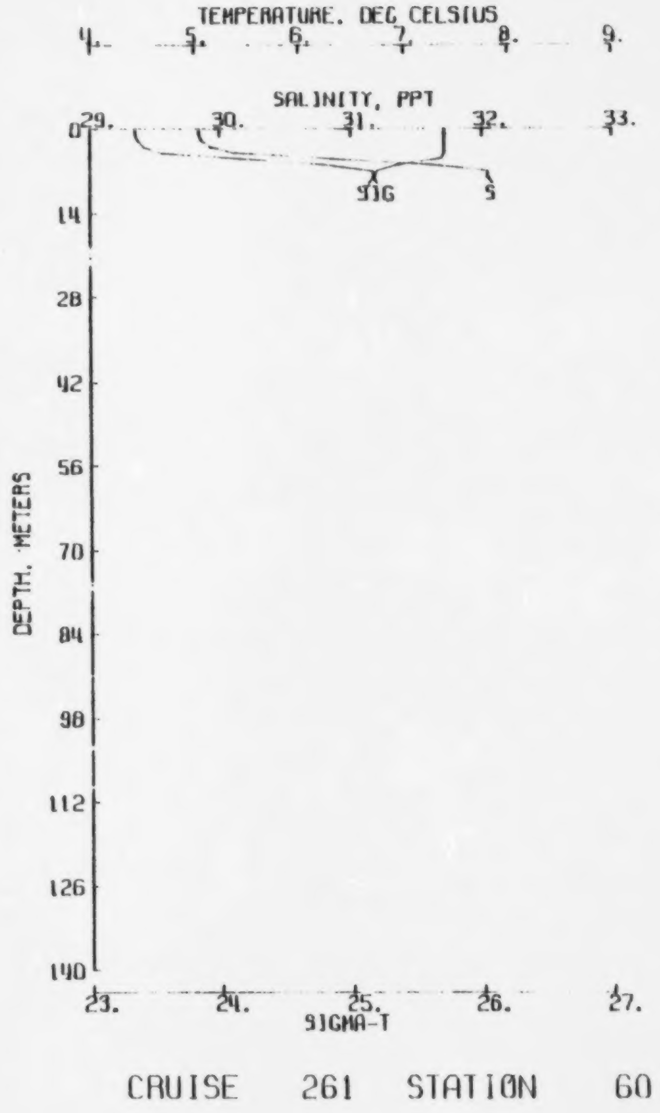


Figure 11. Hydrography and vertical profiles: HEL-2.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  61.       03E     11/ 6/78
---------------------------                                19.3 HOURS GMT

  LATITUDE = 53  52.0N   LONGITUDE = 166  33.4W   SONIC DEPTH =   16 M

  1-DIGIT WEATHER CODE IS (X7) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (6) ---STRATOCUMULUS       .
  CLOUD AMOUNT --- (9) ---8/8 TOTAL     .
  VISIBILITY --- (7) ---10-20 KM
-----------------------------------------------------------------------
I          DIRECTION         SPEED                                    I
I WIND     135 - 144 DEGR    20 KNOTS                                 I
-----------------------------------------------------------------------
I          DIRECTION         HEIGHT      PERIOD                       I
I SEA        0 -   0 DEGR      M.           SECS                      I
I SWELL        -     DEGR      M.           SECS                      I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =    8.3 DEGR C.   BAROMETRIC PR. =1014.9 MB     I
I              -WET =        DEGR C.   TRANSPARENCY   =        M     I
-----------------------------------------------------------------------

          DEPTH       TEMPERATURE   SALINITY      SIGMA-T     DELTA-D
          METERS        DEG C         PPT                      DYN M
            0.           7.18        30.136        23.61      0.
            1.0          7.18        30.136        23.61      0.004
            5.0          6.60        32.074        25.21      0.018
```

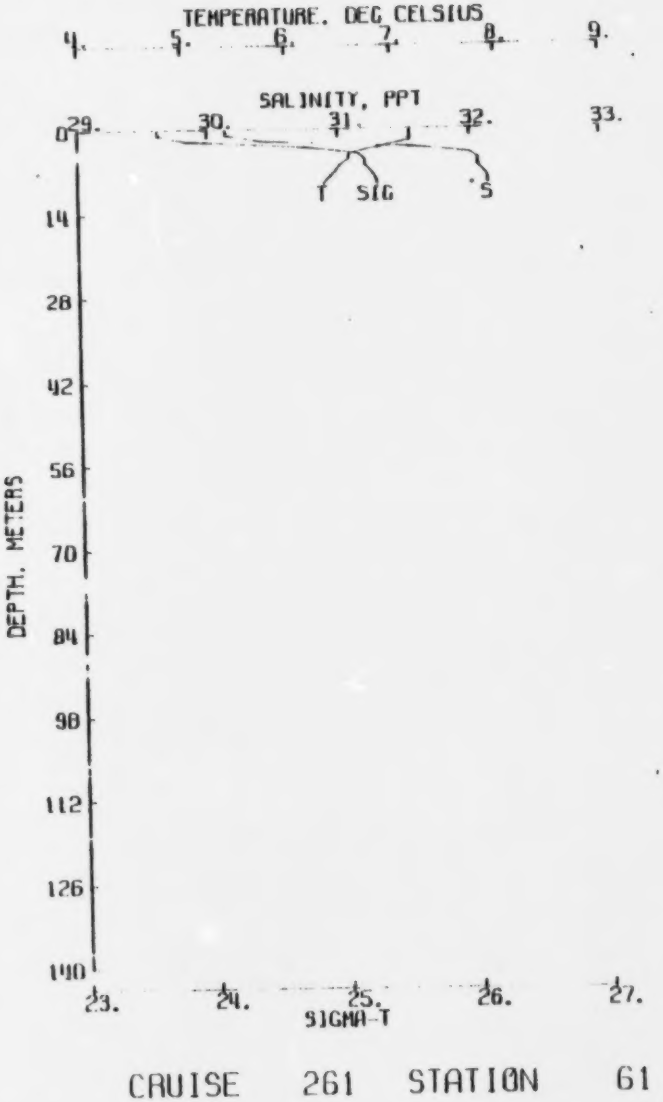
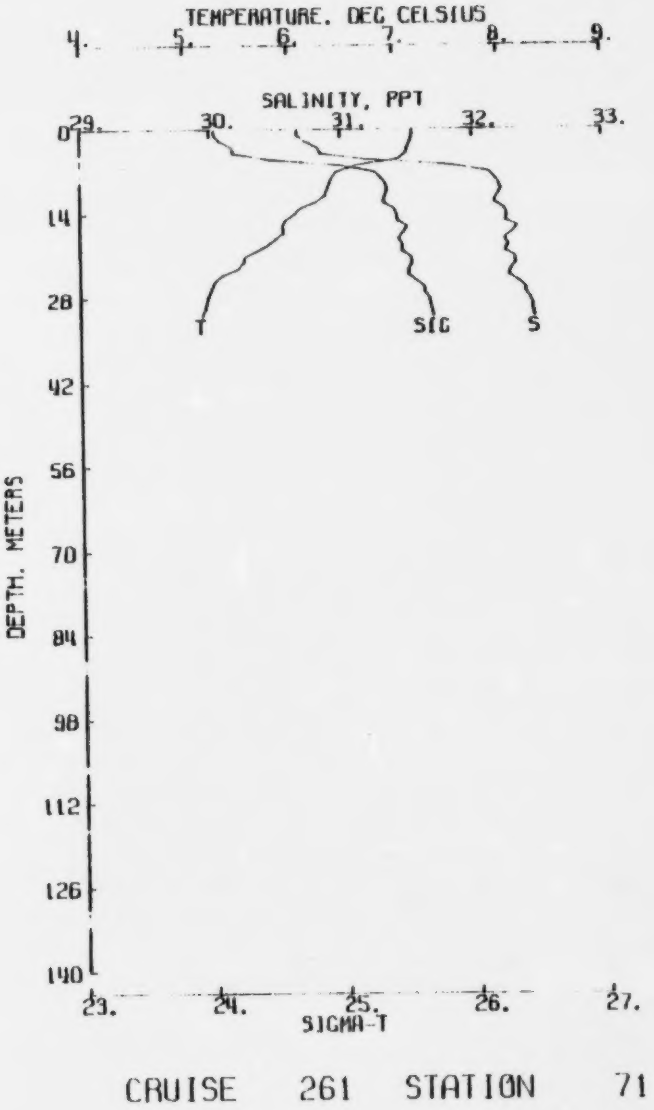


Figure 12. Hydrography and vertical profiles: 3E.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  71.   HEL03A    12/ 6/78
--------------------------                                2.8 HOURS GMT

 LATITUDE = 53  51.5N   LONGITUDE = 166  33.2W   SONIC DEPTH =   40 M

 1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
 CLOUD TYPE --- (7) ---STRATUS
 CLOUD AMOUNT --- (8) ---8/8 TOTAL
 VISIBILITY --- (7) ---10-26 KM
----------------------------------------------------------------------
I          DIRECTION          SPEED                                  I
I WIND     165 - 174 DEGR     15 KNOTS                               I
----------------------------------------------------------------------
I          DIRECTION          HEIGHT       PERIOD                    I
I SEA      165 - 174 DEGR   0.2 M.           SECS                    I
I SWELL        -      DEGR      M.           SECS                    I
----------------------------------------------------------------------
I TEMPERATURES -DRY =  10.0 DEGR C.   BAROMETRIC PR. =1008.9 MB      I
I              -WET =       DEGR C.   TRANSPARENCY   =       M       I
----------------------------------------------------------------------

        DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS        DEG C         PPT                       DYN M
          0.          7.18        30.671        24.03        0.
          1.0         7.18        30.671        24.03        0.004
          5.0         7.05        31.194        24.46        0.019
         10.0         6.37        32.221        25.36        0.033
         15.0         5.97        32.261        25.44        0.046
         20.0         5.69        32.251        25.46        0.059
         25.0         5.30        32.349        25.58        0.071
         30.0         5.19        32.468        25.69        0.083
```

Figure 13. Hydrography and vertical profiles: HEL-3A.



```
AC   CRUISE 261 CONSECUTIVE STATION NO.  76.   HEL 03     12/ 6/78
----------------------------                                8.0 HOURS GMT

  LATITUDE : 53  53.2N   LONGITUDE = 166  34.3W   SONIC DEPTH =   49 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- ( ) ---NOT RECORDED       .
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
----------------------------------------------------------------------
I          DIRECTION         SPEED                                   I
I WIND     175 - 184 DEGR     5 KNOTS                                I
----------------------------------------------------------------------
I          DIRECTION         HEIGHT      PERIOD                      I
I SEA       0 -   0 DEGR       M.           SECS                     I
I SWELL       -     DEGR       M.           SECS                     I
----------------------------------------------------------------------
I TEMPERATURES -DRY =  10.6 DEGR C.   BAROMETRIC PR. =1008.0 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M  I
----------------------------------------------------------------------


          DEPTH      TEMPERATURE   SALINITY      SIGMA-T       DELTA-D
          METERS        DEG C        PPT                        DYN M
            0.          7.28        30.570        23.94        0.
            1.0         7.28        30.570        23.94        0.004
            5.0         6.58        31.964        25.13        0.017
           10.0         6.03        32.283        25.45        0.031
           15.0         5.76        32.289        25.48        0.043
           20.0         5.45        32.371        25.58        0.056
           25.0         5.26        32.405        25.63        0.068
           30.0         5.26        32.478        25.69        0.079
           35.0         5.17        32.525        25.74        0.091
           40.0         5.08        32.582        25.79        0.102
```

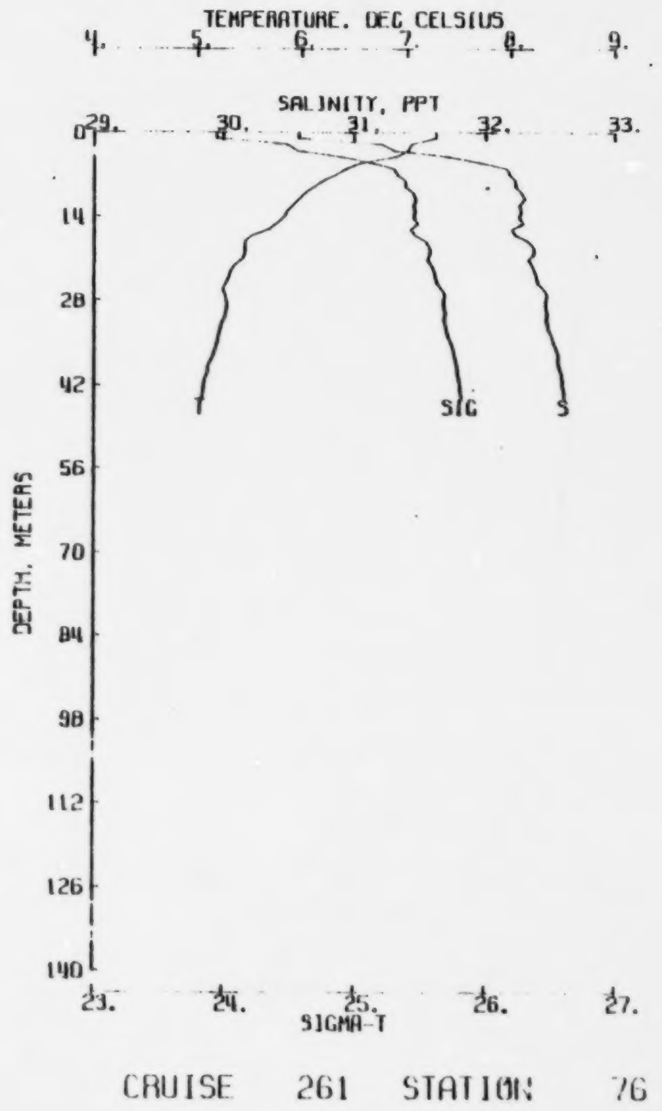


Figure 14. Hydrography and vertical profiles: HEL-3.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  78.   HEL 07     12/ 6/78
-------------------------------                           10.8 HOURS GMT

 LATITUDE = 51  53.6N   LONGITUDE = 166  35.8W   SONIC DEPTH =   98 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- ( ) ---NOT RECORDED
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------
I          DIRECTION         SPEED                              I
I WIND     215 - 224 DEGR    15 KNOTS                           I
-----------------------------------------------------------------
I          DIRECTION         HEIGHT      PERIOD                 I
I SEA      215 - 224 DEGR   0.3 M.         SECS                 I
I SWELL        -     DEGR       M.         SECS                 I
-----------------------------------------------------------------
I TEMPERATURES -DRY =    6.9 DEGR C.   BAROMETRIC PR. =1009.6 MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =        M  I
-----------------------------------------------------------------

       DEPTH     TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
       METERS      DEG C          PPT                       DYN M
         0.         6.41         31.676        24.92        0.
         1.0        6.41         31.676        24.92        0.003
         5.0        6.34         32.236        25.37        0.014
        10.0        6.29         32.261        25.40        0.027
        15.0        5.96         32.303        25.47        0.040
        20.0        5.50         32.336        25.55        0.053
        25.0        5.43         32.375        25.59        0.065
        30.0        5.30         32.427        25.64        0.077
        35.0        5.16         32.528        25.74        0.088
        40.0        5.12         32.568        25.78        0.100
        45.0        5.14         32.578        25.78        0.111
        50.0        5.08         32.598        25.80        0.122
        60.0        4.97         32.651        25.86        0.144
        70.0        4.93         32.670        25.88        0.165
        75.0        4.92         32.664        25.87        0.176
        80.0        4.90         32.688        25.90        0.187
        90.0        4.85         32.703        25.91        0.208
```

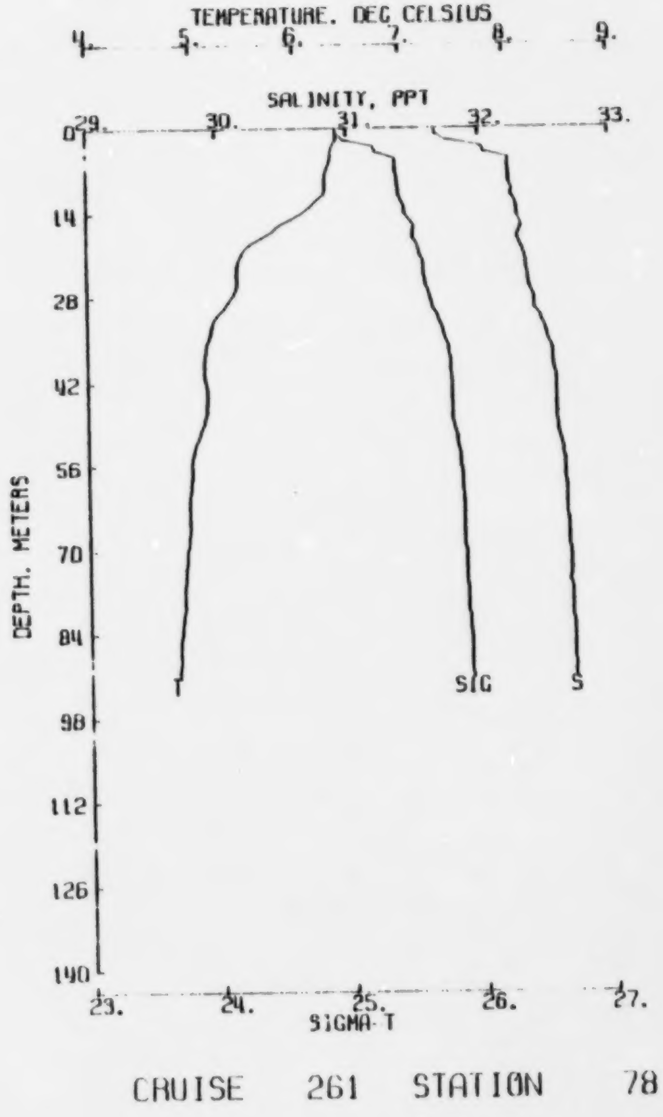


Figure 15. Hydrography and vertical profiles: HEL-7.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  80.         7C     12/ 6/78
--------------------------                                   14.4 HOURS GMT

  LATITUDE = 51  52.6N   LONGITUDE = 166  37.2W   SONIC DEPTH =   62 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (6) ---STRATOCUMULUS
  CLOUD AMOUNT --- (6) ---6/8
  VISIBILITY --- (6) ---4-10 KM
-----------------------------------------------------------------
I         DIRECTION         SPEED                                I
I WIND        -       DEGR       KNOTS                           I
-----------------------------------------------------------------
I         DIRECTION         HEIGHT      PERIOD                   I
I SEA       0 -   0 DEGR        M.         SECS                  I
I SWELL       -     DEGR        M.         SECS                  I
-----------------------------------------------------------------
I TEMPERATURES -DRY =    9.4 DEGR C.   BAROMETRIC PR. =1009.9 MB I
I              -WET =        DEGR C.   TRANSPARENCY    =       M I
-----------------------------------------------------------------

        DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C          PPT                       DYN M
          0.          6.43         30.955        24.35       0.
          1.0         6.43         30.955        24.35       0.004
          5.0         6.34         32.261        25.39       0.015
         10.0         6.17         32.293        25.44       0.028
         15.0         6.06         32.329        25.48       0.041
         20.0         5.95         32.351        25.51       0.053
         25.0         5.77         32.366        25.53       0.066
         30.0         5.56         32.388        25.58       0.078
         35.0         5.39         32.397        25.61       0.090
         40.0         5.19         32.452        25.68       0.102
         45.0         5.15         32.568        25.77       0.113
         50.0         5.09         32.579        25.79       0.124
```

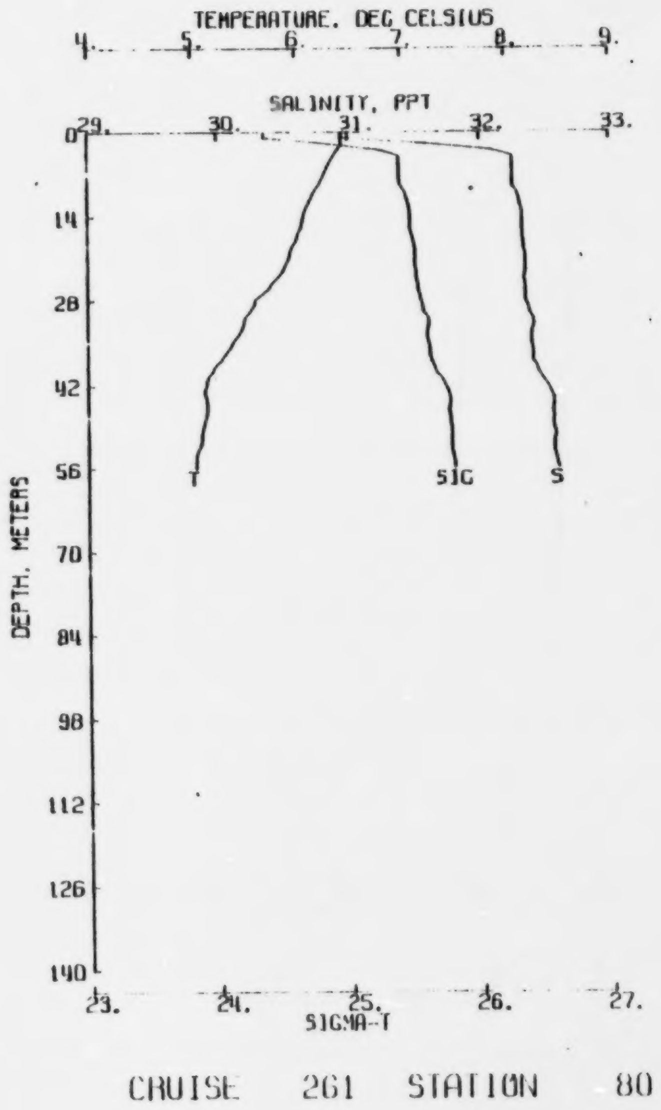


Figure 16. Hydrography and vertical profiles: 7C.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  81.   HEL 6A     12/ 6/78
----------------------------                               14.8 HOURS GMT

  LATITUDE = 51  54.4N   LONGITUDE = 166  36.0W   SONIC DEPTH =  117 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (7) ---STRATUS
  CLOUD AMOUNT --- (6) ---6/8
  VISIBILITY --- (7) ---10-20 KM
-----------------------------------------------------------------------
I          DIRECTION        SPEED                                     I
I WIND         -      DEGR       KNOTS                                I
-----------------------------------------------------------------------
I          DIRECTION        HEIGHT     PERIOD                         I
I SEA        0 -   0 DEGR       M.         SECS                       I
I SWELL        -     DEGR       M.         SECS                       I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =   7.8 DEGR C.   BAROMETRIC PR. =1009.7 MB       I
I              -WET =       DEGR C.   TRANSPARENCY   =       M        I
-----------------------------------------------------------------------

       DEPTH      TEMPERATURE    SALINITY      SIGMA-T       DELTA-D
       METERS       DEG C          PPT                        DYN M
         0.         6.47         31.853        25.05         0.
         1.0        6.47         31.853        25.05         0.003
         5.0        6.42         32.122        25.27         0.014
        10.0        6.19         32.265        25.41         0.027
        15.0        5.93         32.254        25.43         0.040
        20.0        5.55         32.398        25.59         0.053
        25.0        5.51         32.350        25.56         0.065
        30.0        5.33         32.415        25.63         0.077
        35.0        5.12         32.547        25.76         0.088
        40.0        5.06         32.596        25.80         0.099
        45.0        5.04         32.609        25.82         0.110
        50.0        5.00         32.632        25.84         0.121
        60.0        4.96         32.653        25.86         0.143
        70.0        4.93         32.668        25.88         0.165
        75.0        4.91         32.668        25.88         0.175
        80.0        4.88         32.684        25.89         0.186
        90.0        4.87         32.697        25.91         0.207
       100.0        4.85         32.709        25.92         0.228
```

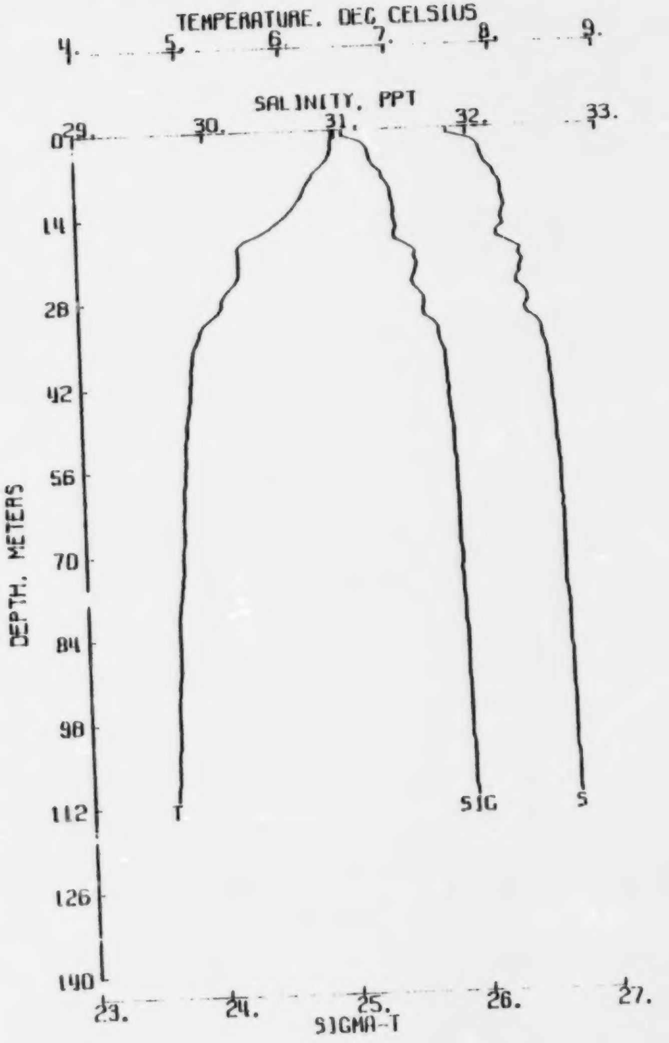
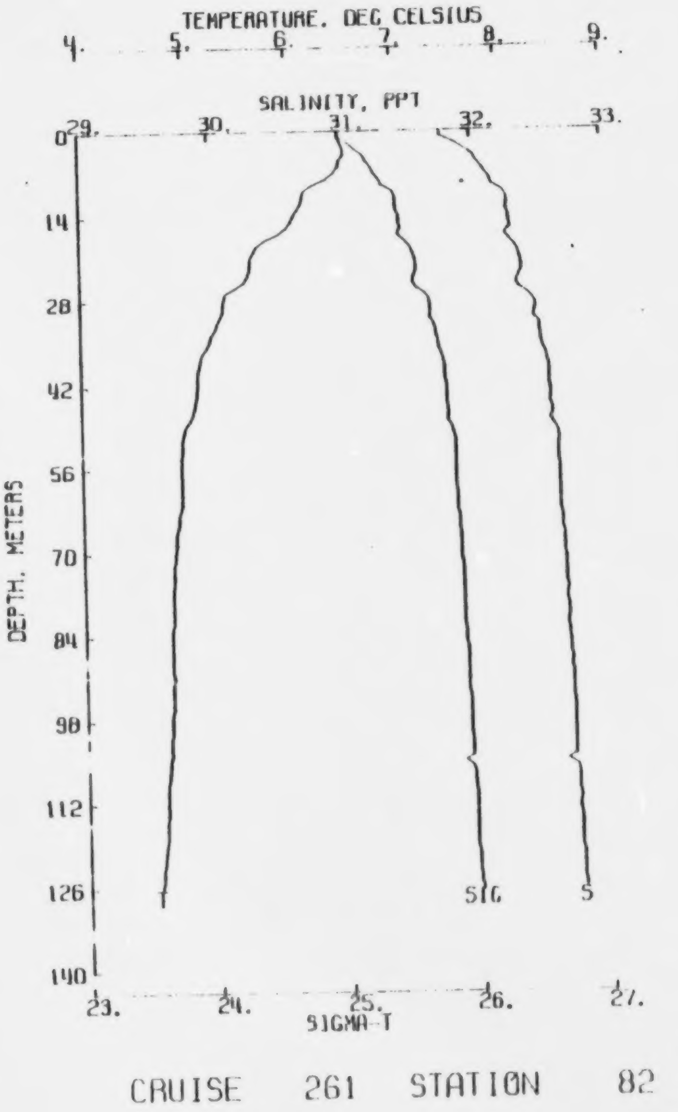


Figure 17. Hydrography and vertical profiles: HEL-6A.

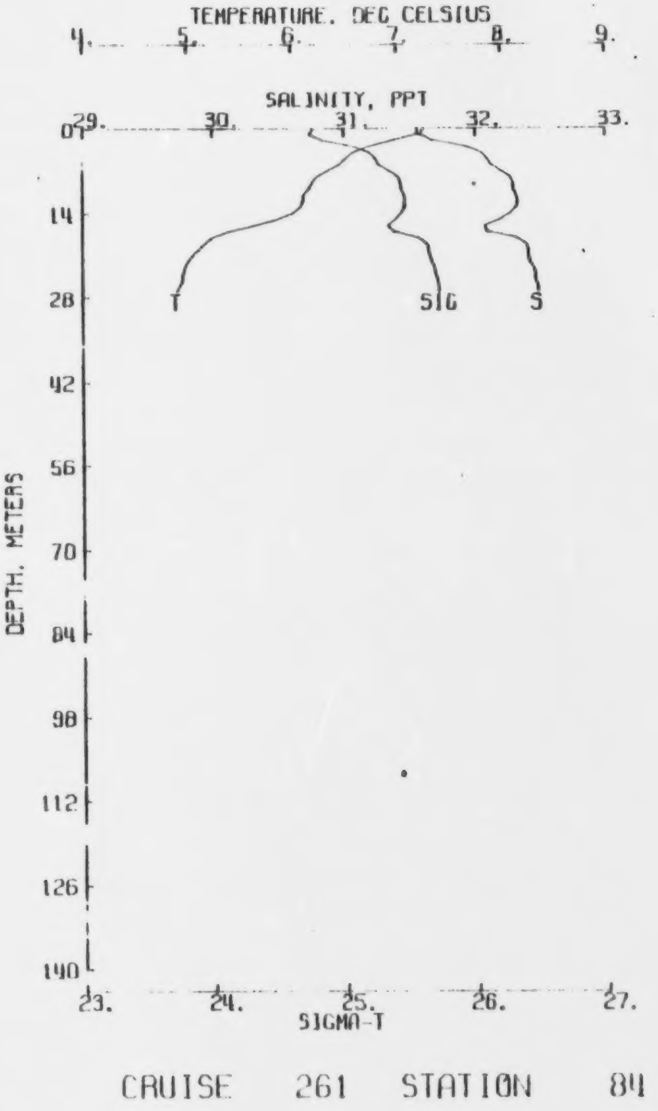
```
AC   CRUISE 261 CONSECUTIVE STATION NO.  82.   HEL 06     12/ 6/78
------------------------------                          15.4 HOURS GMT

 LATITUDE = 53  55.2N   LONGITUDE = 166  35.9W   SONIC DEPTH =  132 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- (7) ---STRATUS
 CLOUD AMOUNT --- (6) ---6/8
 VISIBILITY --- (7) ---10-20 KM
-----------------------------------------------------------------------
I          DIRECTION          SPEED                                   I
I WIND         -       DEGR    KNOTS                                  I
-----------------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                      I
I SEA        0 -   0 DEGR        M.          SECS                     I
I SWELL        -     DEGR        M.          SECS                     I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =    7.9 DEGR C.   BAROMETRIC PR. =1009.9 MB      I
I              -WET =        DEGR C.   TRANSPARENCY   =        M      I
-----------------------------------------------------------------------

     DEPTH      TEMPERATURE   SALINITY     SIGMA-T      DELTA-D
     METERS        DEG C        PPT                      DYN M
       0.          6.51        31.780       24.99       0.
       1.0         6.51        31.780       24.99       0.003
       5.0         6.50        32.051       25.21       0.014
      10.0         6.15        32.248       25.40       0.028
      15.0         6.02        32.292       25.45       0.041
      20.0         5.67        32.362       25.55       0.053
      25.0         5.56        32.344       25.55       0.066
      30.0         5.36        32.479       25.68       0.077
      35.0         5.23        32.531       25.73       0.089
      40.0         5.12        32.563       25.79       0.100
      45.0         5.09        32.585       25.79       0.111
      50.0         4.98        32.637       25.85       0.122
      60.0         4.94        32.656       25.87       0.144
      70.0         4.88        32.680       25.89       0.165
      75.0         4.85        32.689       25.90       0.176
      80.0         4.95        32.693       25.91       0.187
      90.0         4.84        32.719       25.93       0.208
     100.0         4.91        32.733       25.94       0.229
     125.0         4.69        32.766       25.99       0.280
```

Figure 18. Hydrography and vertical profiles: HEL-6.



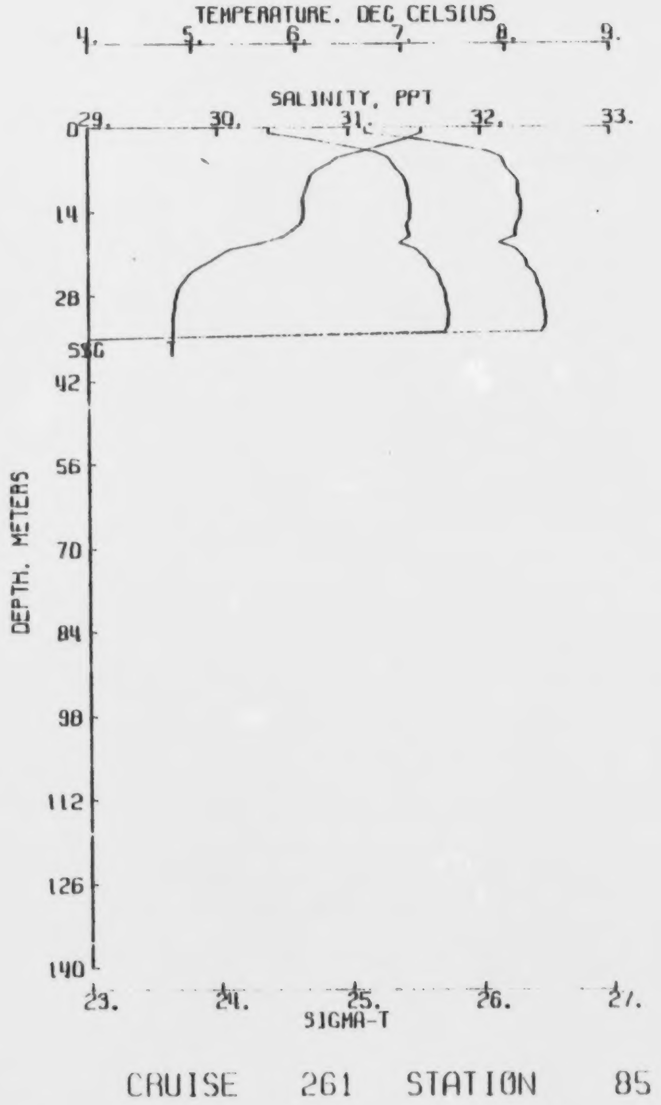
```
AC   CRUISE 261 CONSECUTIVE STATION NO.  84.    DUT OA      12/ 6/78
------------------------------                              21.0 HOURS GMT

  LATITUDE = 53  54.1N   LONGITUDE = 166  29.2W   SONIC DEPTH =   29 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (5) ---STRATOCUMULUS      .
  CLOUD AMOUNT --- (7) ---7/8            .
  VISIBILITY --- (3) ---20-50 KM
-----------------------------------------------------------------
I          DIRECTION        SPEED                                I
I WIND     205 - 214 DEGR    8 KNOTS                             I
-----------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                 I
I SEA        0 -    0 DEGR       0.          SECS                I
I SWELL        -      DEGR       M.          SECS                I
-----------------------------------------------------------------
I TEMPERATURES -DRY =  11.7 DEGR C.   BAROMETRIC PR. =1009.2 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =       M   I
-----------------------------------------------------------------

         DEPTH      TEMPERATURE   SALINITY      SIGMA-T       DELTA-D
         METERS       DEG C         PPT                        DYN M
           0.          7.20        31.609        24.77         0.
           1.0         7.21        31.575        24.74         0.003
           5.0         6.52        32.098        25.24         0.015
          10.0         6.16        32.293        25.44         0.028
          15.0         5.85        32.193        25.40         0.041
          20.0         5.11        32.411        25.65         0.053
          25.0         4.96        32.472        25.72         0.065
```

Figure 19. Hydrography and vertical profiles: DUT-OA.



```
AC   CRUISE 261 CONSECUTIVE STATION NO.  85.    DUT 00      12/ 6/78
---------------------------                                23.0 HOURS GMT

 LATITUDE = 53  53.5N   LONGITUDE = 166  30.8W   SONIC DEPTH =    33 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- (6) ---STRATOCUMULUS      .
 CLOUD AMOUNT --- (6) ---6/8            .
 VISIBILITY --- (8) ---20-50 KM
-----------------------------------------------------------------
I          DIRECTION          SPEED                             I
I WIND     185 - 194 DEGR     5 KNOTS                           I
-----------------------------------------------------------------
I          DIRECTION         HEIGHT      PERIOD                 I
I SEA        0 -    0 DEGR       M.        SECS                 I
I SWELL           -   DEGR       M.        SECS                 I
-----------------------------------------------------------------
I TEMPERATURES -DRY =  12.8 DEGR C.   BAROMETRIC PR. =1008.9 MB I
I              -WET =       DEGR C.   TRANSPARENCY   =       M  I
-----------------------------------------------------------------

        DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C          PPT                        DYN M
          0.          7.20         31.126        24.39        0.
          1.0         7.20         31.126        24.39        0.004
          5.0         6.39         32.163        25.31        0.016
         10.0         6.10         32.295        25.45        0.029
         15.0         6.06         32.307        25.46        0.041
         20.0         5.36         32.267        25.51        0.054
         25.0         4.94         32.438        25.69        0.066
         30.0         4.93         32.492        25.75        0.078
         35.0         4.81         27.968        22.17        0.091
```

Figure 20. Hydrography and vertical profiles: DUT-00.



```
AC   CRUISE 261 CONSECUTIVE STATION NO.  86.   DUT OB     13/ 6/78
------------------------------                           0.1 HOURS GMT

 LATITUDE = 51  54.4N   LONGITUDE = 166  29.0W   SONIC DEPTH =   22 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (6) ---6/8
 VISIBILITY --- (8) ---20-50 KM
--------------------------------------------------------------------------
I          DIRECTION          SPEED                                      I
I WIND    165 - 194 DEGR     6 KNOTS                                     I
--------------------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                         I
I SEA        0 -    0 DEGR       M.          SECS                        I
I SWELL         -     DEGR       M.          SECS                        I
--------------------------------------------------------------------------
I TEMPERATURES -DRY =  12.8 DEGR C.   BAROMETRIC PR. =1008.9 MB          I
I              -WET =       DEGR C.   TRANSPARENCY   =        M          I
--------------------------------------------------------------------------

         DEPTH      TEMPERATURE    SALINITY     SIGMA-T      DELTA-D
         METERS       DEG C          PPT                      DYN M
           0.          7.04        31.706       24.86        0.
           1.0         7.04        31.706       24.86        0.003
           5.0         6.72        32.026       25.16        0.015
          10.0         6.23        32.247       25.39        0.028
          15.0         6.06        32.320       25.47        0.041
          20.0         5.94        32.304       25.47        0.053
```

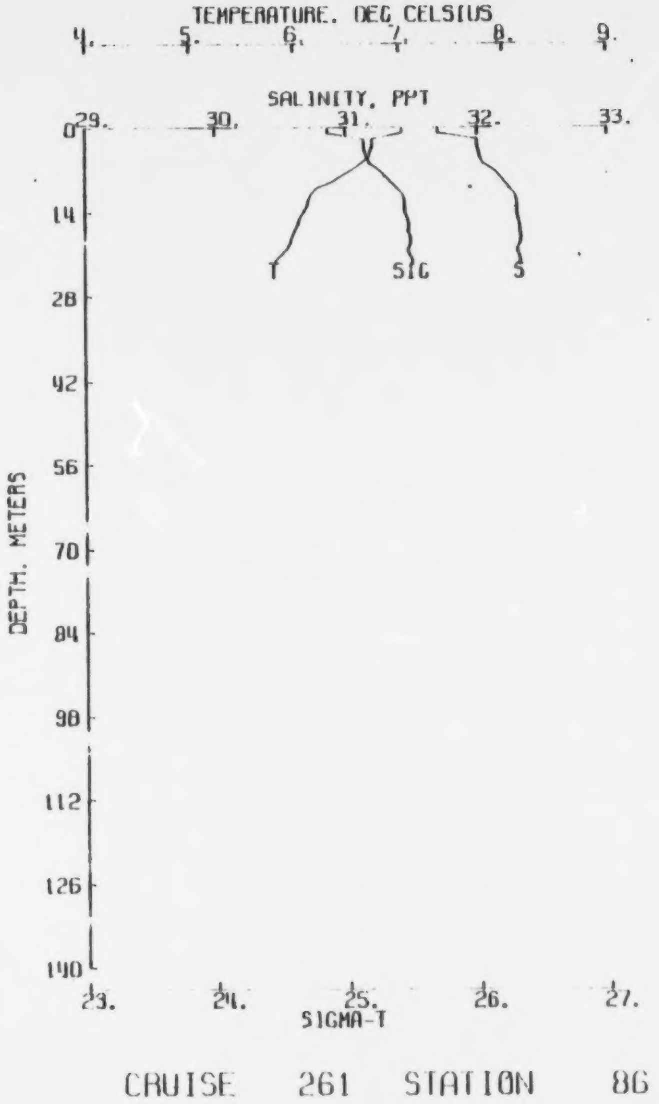


Figure 21. Hydrography and vertical profiles: DUT-OB.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  87.   HEL 01     13/ 6/78
---------------------------                                0.6 HOURS GMT

 LATITUDE = 5[illegible] 56.0N   LONGITUDE = 166  34.0W   SONIC DEPTH =   79 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (6) ---6/8
 VISIBILITY --- (8) ---20-50 KM
-------------------------------------------------------------------------
I         DIRECTION        SPEED                                         I
I WIND    195 - 204 DEGR    7 KNOTS                                      I
-------------------------------------------------------------------------
I         DIRECTION         HEIGHT     PERIOD                            I
I SEA     195 - 204 DEGR  0.2 M.          SECS                           I
I SWELL       -     DEGR      M.          SECS                           I
-------------------------------------------------------------------------
I TEMPERATURES -DRY =  12.2 DEGR C.   BAROMETRIC PR. =1008.8 MB          I
I              -WET =       DEGR C.   TRANSPARENCY   =       M           I
-------------------------------------------------------------------------

         DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
         METERS        DEG C          PPT                       DYN M
           0.          7.13         31.392        24.61         0.
           1.0         7.13         31.392        24.61         0.003
           5.0         6.96         31.615        24.80         0.017
          10.0         6.44         32.179        25.31         0.032
          15.0         5.88         32.363        25.53         0.044
          20.0         5.69         32.408        25.59         0.057
          25.0         5.53         32.492        25.67         0.068
          30.0         5.35         32.530        25.72         0.080
          35.0         5.29         32.534        25.73         0.091
          40.0         5.20         32.570        25.77         0.103
          45.0         5.12         32.594        25.80         0.114
          50.0         5.07         32.614        25.82         0.125
          60.0         5.06         32.647        25.85         0.147
          70.0         4.89         32.693        25.90         0.168
          75.0         4.87         32.711        25.92         0.179
          80.0         4.86         32.730        25.93         0.189
```

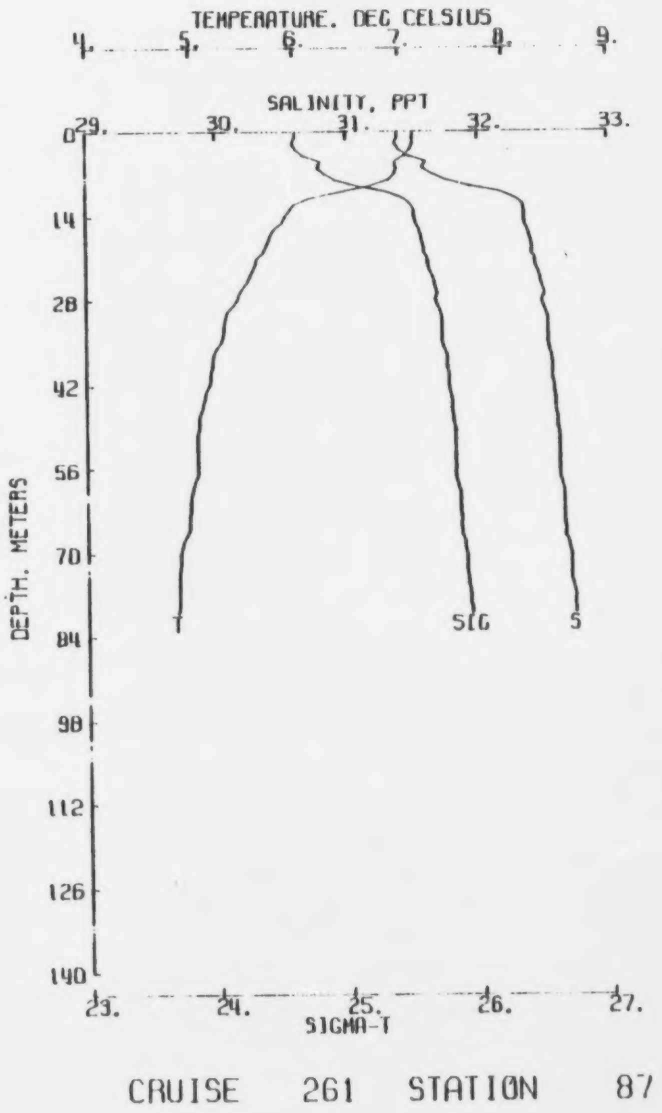


Figure 22. Hydrography and vertical profiles: HEL-1.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  88.         3H     13/ 6/78
----------------------------                                 1.2 HOURS GMT

  LATITUDE = 53  53.7N   LONGITUDE = 166  32.5W   SONIC DEPTH =    37 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (6) ---STRATOCUMULUS
  CLOUD AMOUNT --- (7) ---7/8
  VISIBILITY --- (8) ---20-50 KM
-------------------------------------------------------------------------
I [redacted]     DIRECTION         SPEED                                    I
I WI[redacted]D  215 - 224 DEGS    7 KNOTS                                  I
-------------------------------------------------------------------------
I [redacted]     DIRECTION         HEIGHT     PERIOD                        I
I SE[redacted]   215 - 224 DEGR  0.2 M.       SECS                          I
I SWELL            -     DEGR       M.       SECS                          I
-------------------------------------------------------------------------
I TEMPERATURES -DRY =  12.8 DEGR C.   BAROMETRIC PR. =1008.5 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =        M  I
-------------------------------------------------------------------------

        DEPTH     TEMPERATURE   SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C         PPT                       DYN M
         0.          7.48        30.878        24.16       0.
         1.0         7.49        30.868        24.15       0.004
         5.0         7.33        31.002        24.27       0.018
        10.0         6.12        32.227        25.39       0.033
        15.0         5.61        32.298        25.51       0.046
        20.0         5.28        32.392        25.61       0.058
        25.0         5.23        32.420        25.65       0.070
        30.0         5.19        32.494        25.72       0.081
        35.0         5.07        32.536        25.76       0.093
        40.0         5.04        26.594        21.07       0.110
```

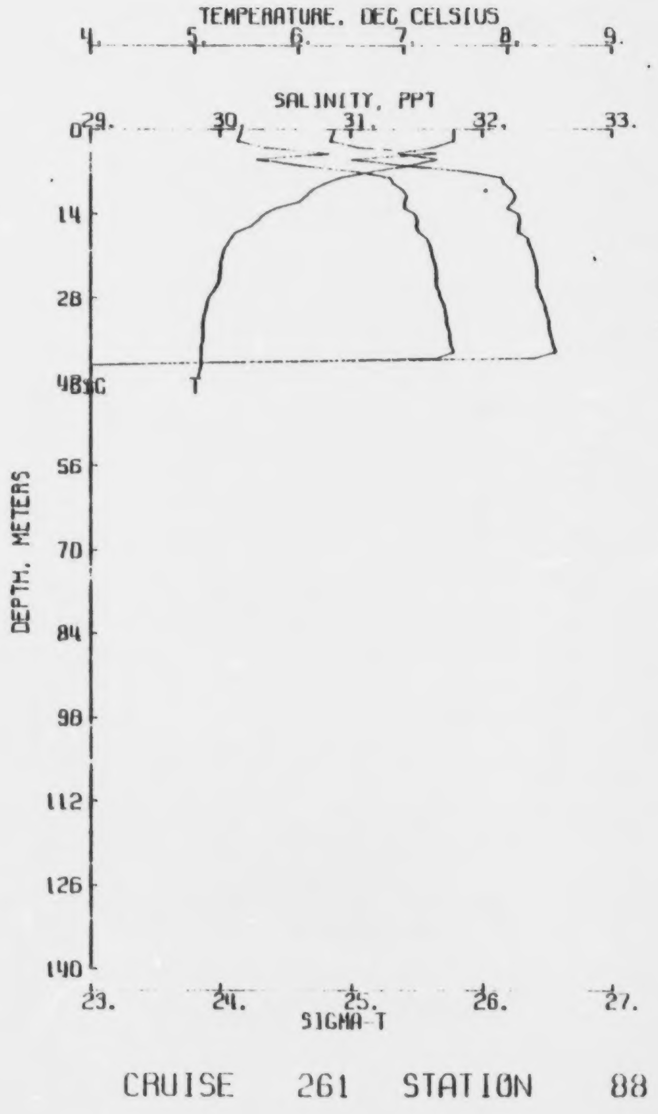


Figure 23. Hydrography and vertical profiles: 3H.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  89.       3AG     13/ 6/78
---------------------------                                   1.8 HOURS GMT

  LATITUDE = 53  53.4N   LONGITUDE = 166  33.3W   SONIC DEPTH =   43 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (6) ---STRATOCUMULUS
  CLOUD AMOUNT --- (7) ---7/8
  VISIBILITY --- (8) ---20-50 KM
----------------------------------------------------------------------
I          DIRECTION          SPEED                                  I
I WIND     225 - 234 DEGR      7 KNOTS                               I
----------------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                     I
I SEA      215 - 224 DEGR   0.2 M.           SECS                    I
I SWELL        -     DEGR      M.            SECS                    I
----------------------------------------------------------------------
I TEMPERATURES -DRY =  12.8 DEGR C.   BAROMETRIC PR. =1008.5 MB     I
I              -WET =       DEGR C.   TRANSPARENCY   =        M     I
----------------------------------------------------------------------

        DEPTH     TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C          PPT                      DYN M
          0.          7.46        31.123        24.35       0.
          1.0         7.45        31.122        24.35       0.004
          5.0         7.26        31.180        24.42       0.018
         10.0         6.29        32.200        25.35       0.033
         15.0         5.72        32.218        25.43       0.046
         20.0         5.27        32.426        25.65       0.058
         25.0         5.17        32.478        25.70       0.070
         30.0         5.13        32.496        25.72       0.081
         35.0         5.08        32.575        25.79       0.093
         40.0         5.04        32.621        25.83       0.104
         45.0         5.03        32.626        25.83       0.115
```

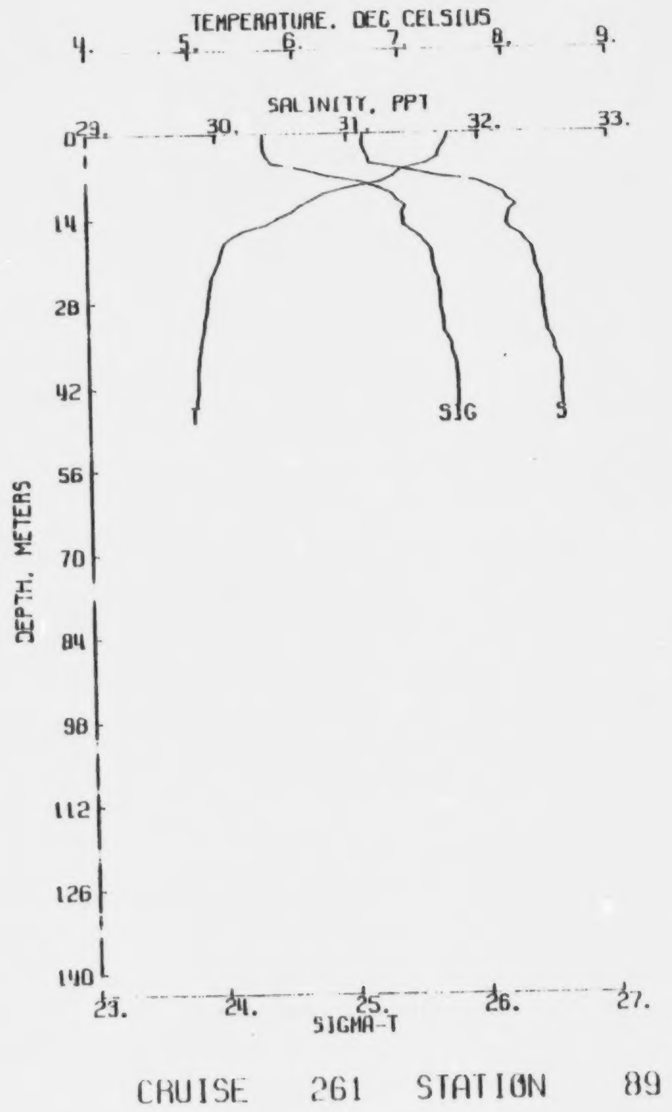
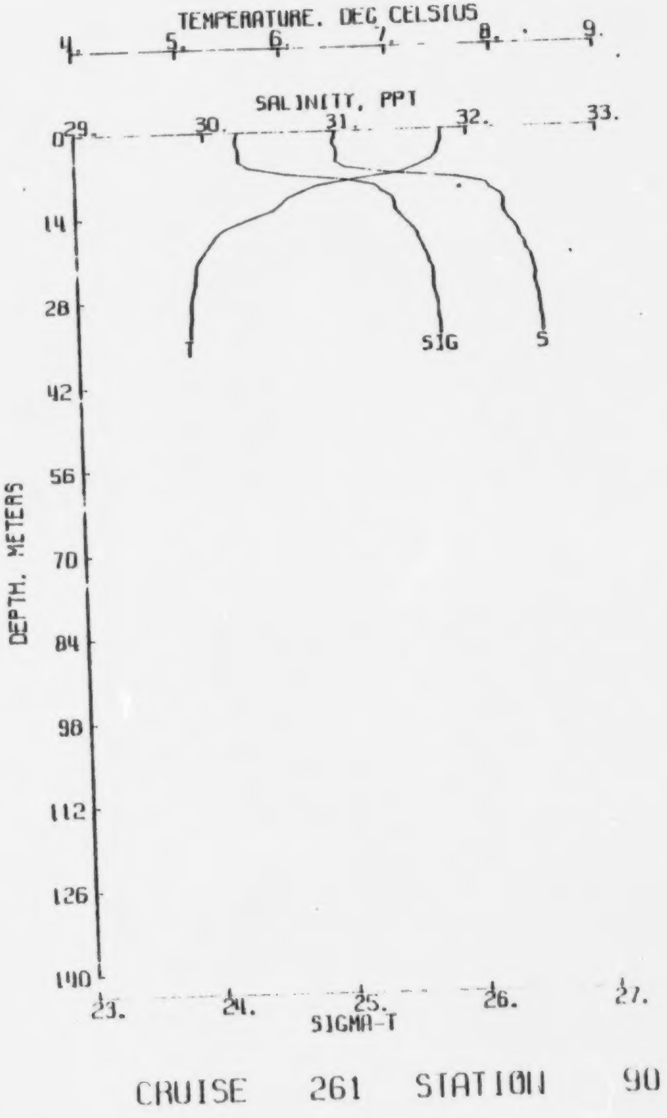


Figure 24. Hydrography and vertical profiles: 3AG.

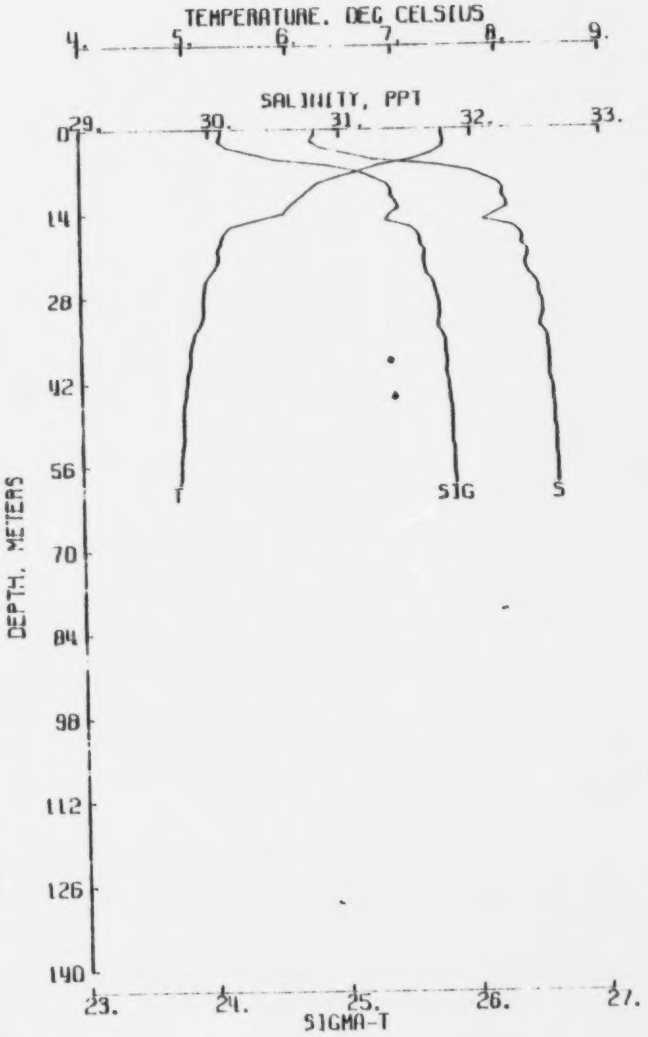
```
AC   CRUISE 261 CONSECUTIVE STATION NO.  90.          3G     13/ 6/78
-----------------------------                                  2.7 HOURS GMT

 LATITUDE = 51  53.5N   LONGITUDE = 166  33.3W   SONIC DEPTH =    32 M

 1-DIGIT WEATHER CODE IS (X)) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (7) ---7/8
 VISIBILITY --- (8) ---20-50 KM
------------------------------------------------------------------
I         DIRECTION        SPEED                                 I
I WIND    215 - 224 DEGR    5 KNOTS                              I
------------------------------------------------------------------
I         DIRECTION         HEIGHT      PERIOD                   I
I SEA       0 -    0 DEGR      M.          SECS                  I
I SWELL        -    DEGR      M.          SECS                   I
------------------------------------------------------------------
I TEMPERATURES -DRY =  12.8 DEGR C.   BAROMETRIC PR. =1008.4 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =       M   I
------------------------------------------------------------------

        DEPTH      TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C          PPT                       DYN M
          0.          7.52        31.016         24.26       0.
          1.0         7.51        30.992         24.24       0.004
          5.0         7.41        31.005         24.27       0.018
         10.0         6.17        32.180         25.35       0.034
         15.0         5.56        32.322         25.53       0.047
         20.0         5.22        32.448         25.67       0.059
         25.0         5.13        32.506         25.73       0.070
         30.0         5.09        32.547         25.76       0.082
```

Figure 25. Hydrography and vertical profiles: 3G.



```
AC   CRUISE 261 CONSECUTIVE STATION NO.  91.        3BF     13/ 6/78
-------------------------------                              3.1 HOURS GMT

 LATITUDE = 53  53.3N   LONGITUDE = 166  33.4W   SONIC DEPTH =   58 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (7) ---7/8
 VISIBILITY --- (8) ---20-50 KM
-------------------------------------------------------------------
I          DIRECTION          SPEED                               I
I WIND     255 - 264 DEGR    12 KNOTS                             I
-------------------------------------------------------------------
I          DIRECTION          HEIGHT      PERIOD                  I
I SEA      255 - 264 DEGR   0.3 M.          SECS                  I
I SWELL        -      DEGR       M.         SECS                  I
-------------------------------------------------------------------
I TEMPERATURES -DRY =  12.2 DEGR C.   BAROMETRIC PR. =1008.5 MB   I
I              -WET =       DEGR C.   TRANSPARENCY   =        M   I
-------------------------------------------------------------------


        DEPTH       TEMPERATURE    SALINITY       SIGMA-T       DELTA-D
        METERS         DEG C         PPT                         DYN M
          0.           7.49         30.800         24.09        0.
          1.0          7.49         30.800         24.09        0.004
          5.0          7.21         31.261         24.49        0.019
         10.0          6.21         32.251         25.40        0.033
         15.0          5.69         32.100         25.34        0.046
         20.0          5.32         32.428         25.64        0.058
         25.0          5.21         32.485         25.70        0.070
         30.0          5.17         32.551         25.76        0.081
         35.0          5.07         32.583         25.79        0.093
         40.0          5.03         32.590         25.80        0.104
         45.0          4.99         32.622         25.83        0.115
         50.0          4.97         32.637         25.85        0.126
```

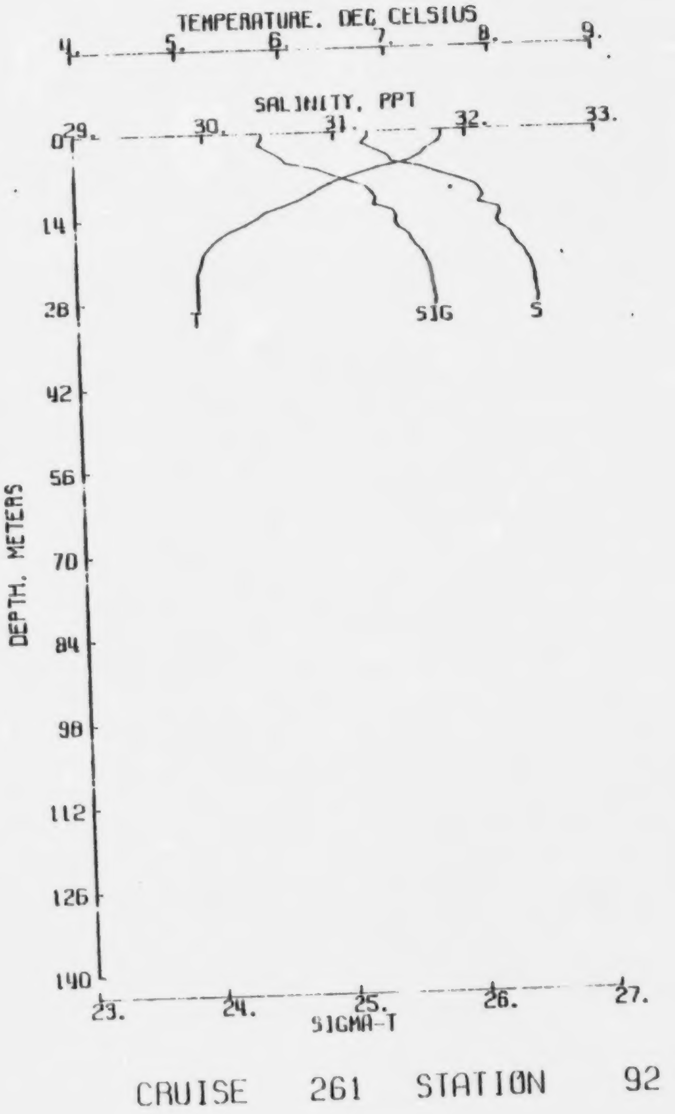
Figure 26. Hydrography and vertical profiles: 3BF.



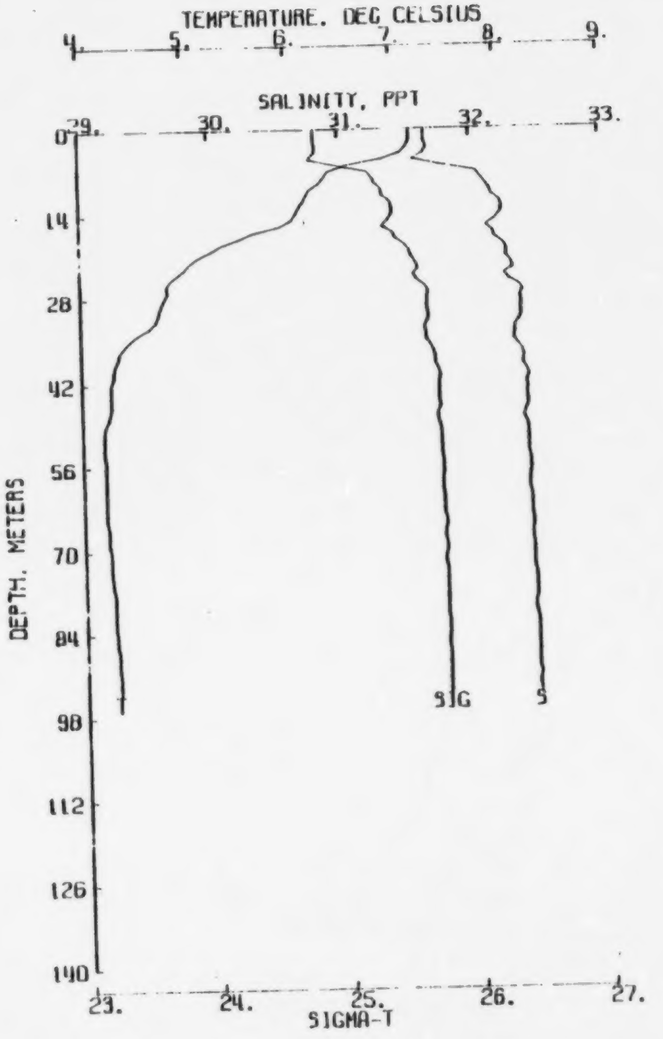
CRUISE 261 STATION 91

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  92.      3DE     13/ 6/78
                                                          4.2 HOURS GMT
-----------------------------
 LATITUDE = 53  52.9N   LONGITUDE = 166  33.4W   SONIC DEPTH =   26 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (8) ---8/8 TOTAL
 VISIBILITY --- (7) ---10-20 KM
-----------------------------------------------------------------
I            DIRECTION           SPEED                              I
I WIND       225 - 234 DEGR      10 KNOTS                           I
-----------------------------------------------------------------
I            DIRECTION           HEIGHT       PERIOD                I
I SEA          0 -   9 DEGR         M.           SECS               I
I SWELL            -   DEGR         M.           SECS               I
-----------------------------------------------------------------
I TEMPERATURES -DRY =    9.4 DEGR C.   BAROMETRIC PR. =1008.5 MB    I
I              -WET =        DEGR C.   TRANSPARENCY   =        M    I
-----------------------------------------------------------------

        DEPTH     TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C         PPT                       DYN M
          0.         7.53        31.258         24.45        0.
          1.0        7.53        31.258         24.45        0.003
          5.0        7.21        31.437         24.63        0.017
         10.0        6.28        32.109         25.28        0.032
         15.0        5.64        32.226         25.45        0.045
         20.0        5.23        32.433         25.66        0.057
         25.0        5.16        32.519         25.73        0.069
```

Figure 27. Hydrography and vertical profiles: 3DE.



```
AC   CRUISE 261 CONSECUTIVE STATION NO.  93.   HEL 04    13/ 6/78
                                                           4.7 HOURS GMT
-----------------------------
 LATITUDE = 51  52.2N  LONGITUDE = 166  34.4W   SONIC DEPTH =   95 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- (6) ---STRATOCUMULUS
 CLOUD AMOUNT --- (7) ---7/8
 VISIBILITY --- (7) ---10-20 KM
-----------------------------------------------------------------
I          DIRECTION          SPEED                             I
I WIND     205 - 214 DEGR       KNOTS                           I
-----------------------------------------------------------------
I          DIRECTION         HEIGHT     PERIOD                  I
I SEA        0 -    0 DEGR       M.        SECS                 I
I SWELL        -      DEGR       M.        SECS                 I
-----------------------------------------------------------------
I TEMPERATURES -DRY =  10.0 DEGR C.   BAROMETRIC PR. =1008.1 MB  I
I              -WET =       DEGR C.   TRANSPARENCY   =       M  I
-----------------------------------------------------------------

      DEPTH     TEMPERATURE    SALINITY      SIGMA-T      DELTA-D
      METERS       DEG C          PPT                      DYN M
        0.         7.18         31.663        24.81       0.
        1.0        7.18         31.663        24.81       0.003
        5.0        6.92         31.569        24.77       0.016
       10.0        6.23         32.160        25.33       0.030
       15.0        6.04         32.185        25.37       0.043
       20.0        5.26         32.284        25.54       0.056
       25.0        4.86         32.299        25.59       0.068
       30.0        4.76         32.373        25.66       0.080
       35.0        4.46         32.313        25.64       0.092
       40.0        4.31         32.411        25.74       0.103
       45.0        4.28         32.417        25.75       0.114
       50.0        4.22         32.416        25.75       0.126
       60.0        4.22         32.422        25.75       0.148
       70.0        4.25         32.449        25.77       0.171
       75.0        4.26         32.454        25.78       0.182
       80.0        4.28         32.449        25.77       0.193
       90.0        4.32         32.472        25.78       0.216
```

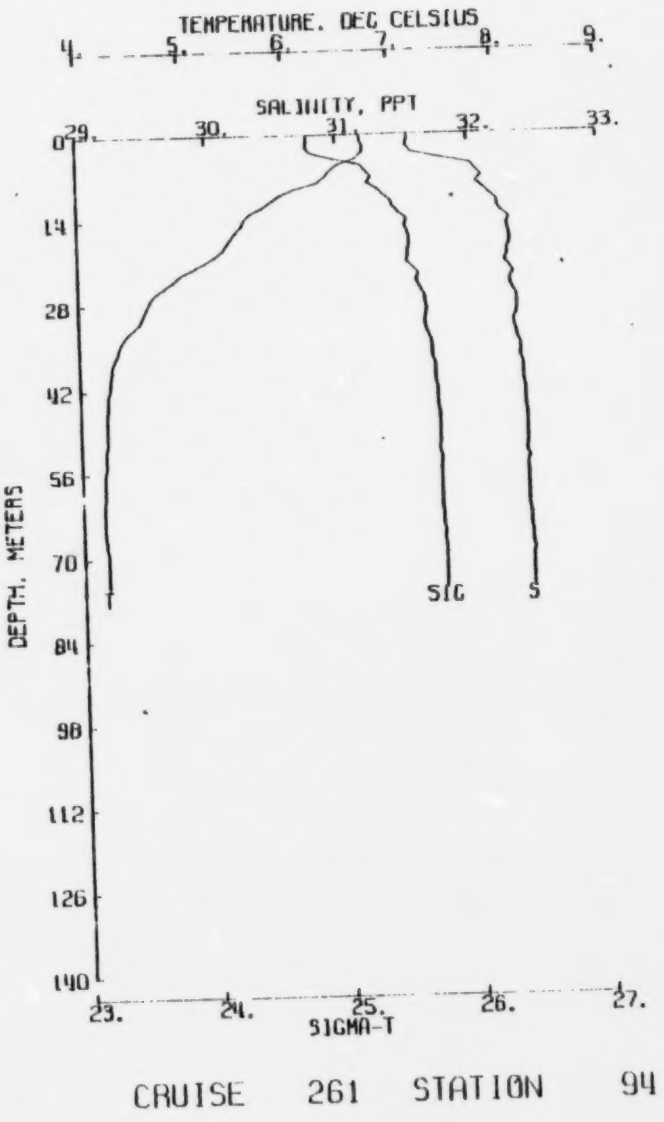


CRUISE 261 STATION 93

Figure 28. Hydrography and vertical profiles: HEL-4.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  94.        4A    13/ 6/78
-----------------------------                                6.1 HOURS GMT

 LATITUDE = 53  51.3N   LONGITUDE = 166  35.0W   SONIC DEPTH =   78 M

 1-DIGIT WEATHER CODE 1, (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- (6) ---STRATOCUMULUS      .
 CLOUD AMOUNT --- (7) ---7/8            .
 VISIBILITY --- (7) ---10-20 KM
-----------------------------------------------------------------------
I          DIRECTION           SPEED                                  I
I WIND     205 - 214 DEGR     7 KNOTS                                 I
-----------------------------------------------------------------------
I          DIRECTION        HEIGHT      PERIOD                        I
I SEA       0 -    0 DEGR      M.          SECS                       I
I SWELL        -     DEGR      M.          SECS                       I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =  10.0 DEGR C.   BAROMETRIC PR. =1008.0 MB      I
I              -WET =       DEGR C.   TRANSPARENCY   =        M      I
-----------------------------------------------------------------------

        DEPTH      TEMPERATURE     SALINITY      SIGMA-T      DELTA-D
        METERS       DEG C           PPT                        DYN M
         0.           6.73          31.544        24.78        0.
         1.0          6.73          31.544        24.78        0.003
         5.0          6.52          32.026        25.18        0.016
        10.0          5.96          32.169        25.36        0.029
        15.0          5.57          32.291        25.51        0.042
        20.0          5.32          32.292        25.54        0.054
        25.0          4.83          32.320        25.61        0.066
        30.0          4.61          32.351        25.66        0.078
        35.0          4.39          32.383        25.71        0.090
        40.0          4.30          32.402        25.73        0.101
        45.0          4.26          32.412        25.74        0.113
        50.0          4.25          32.417        25.75        0.124
        60.0          4.22          32.418        25.75        0.147
        70.0          4.24          32.448        25.77        0.169
        75.0          4.24          32.445        25.77        0.180
```

Figure 29. Hydrography and vertical profiles: 4A.



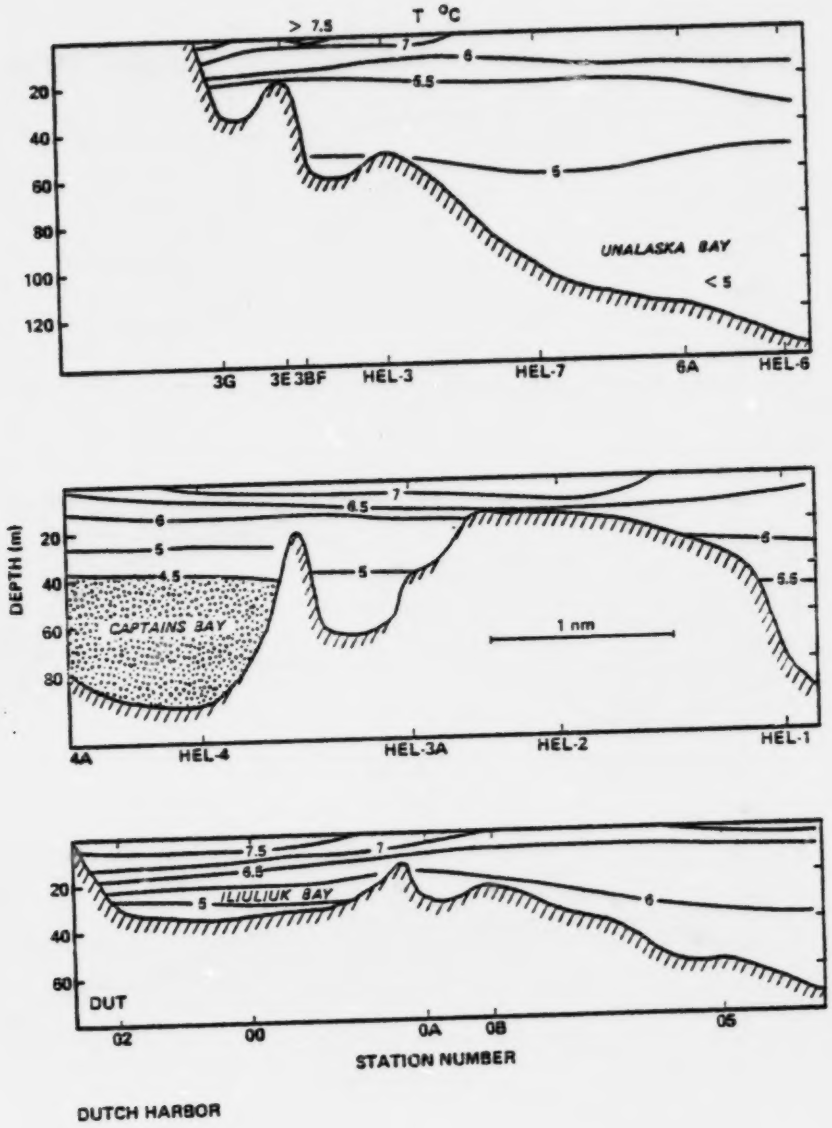


Figure 30. Longitudinal temperature profiles.

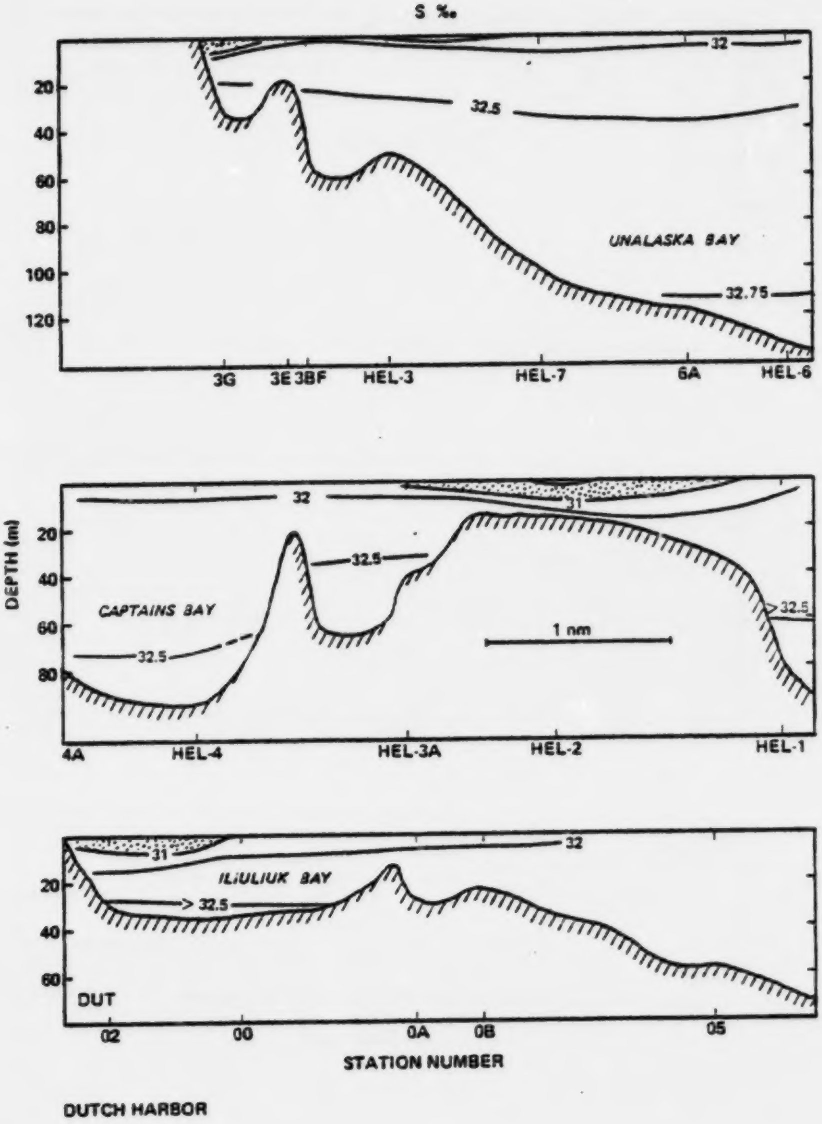


Figure 31. Longitudinal salinity profiles.

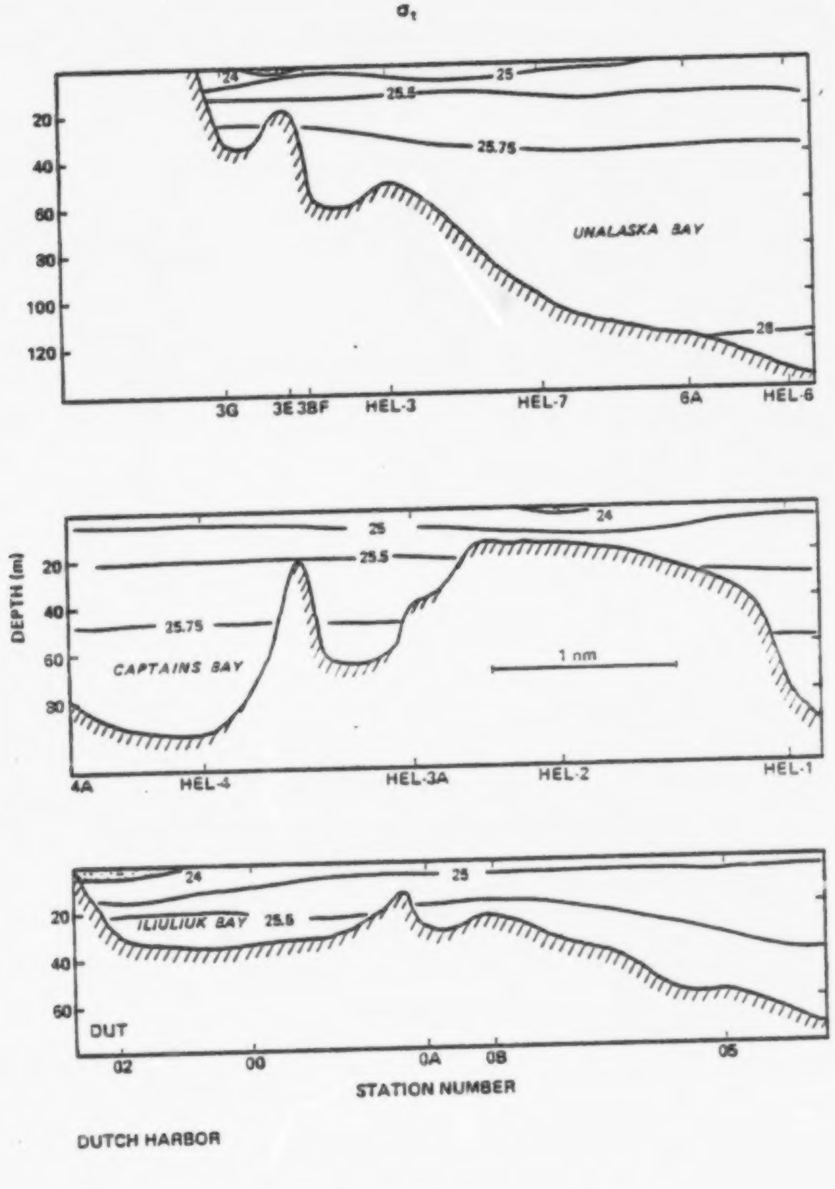


Figure 32. Longitudinal density profiles.

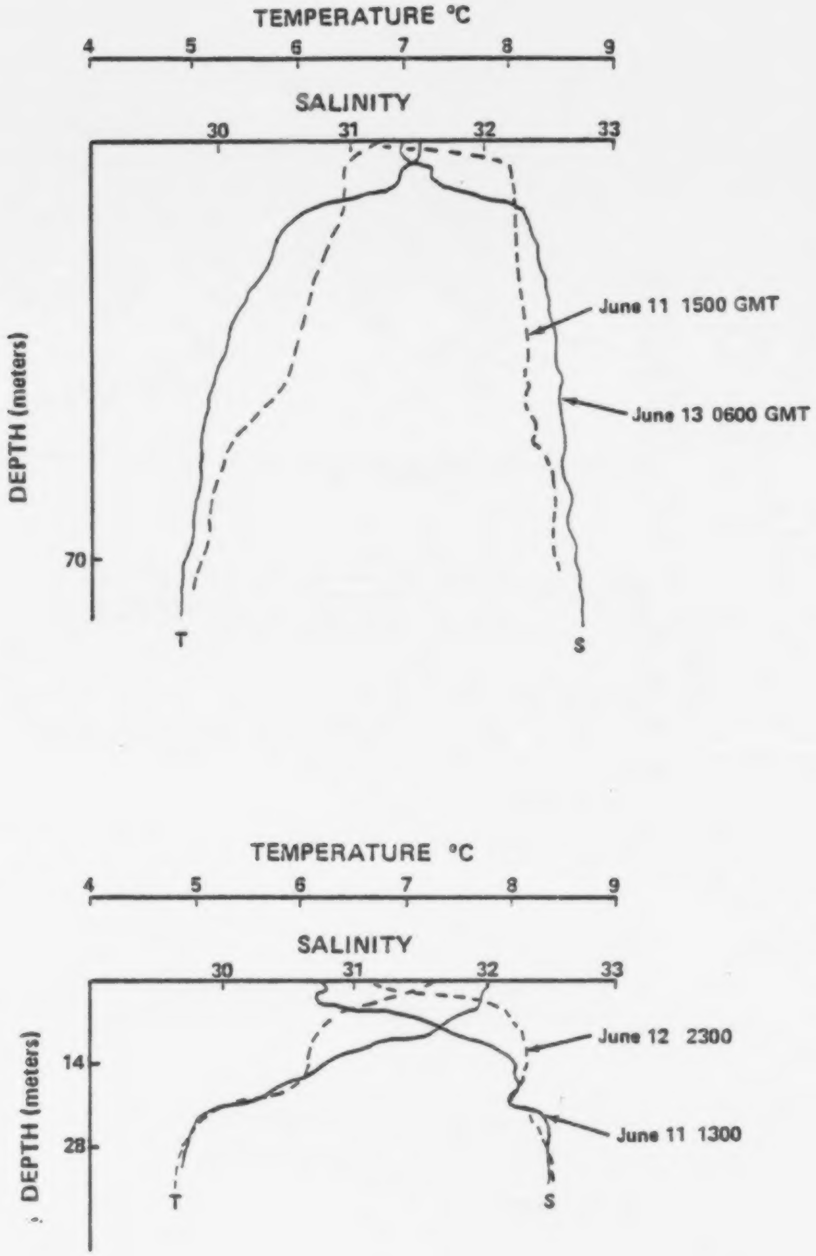


Figure 33. Short term temperature and salinity changes at Stations HEL-1 and DUT-00. T = temperature, S = salinity.

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  55.   DUT001    11/ 6/78
--------------------------------------------              10.0 HOURS GMT

  LATITUDE = 53  55.29   LONGITUDE = 166  31.29   SONIC DEPTH =   29 M

  1-DIGIT WEATHER CODE IS (X?) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
I          DIRECTION           SPEED                                  I
I WIND     1[illegible] - 134 DEGS       5 KNOTS                               I
-----------------------------------------------------------------------
I          DIRECTION        HEIGHT       PERIOD                       I
I SEA        0 -    0 DEGS     M.           SECS                      I
I SWELL       -       DEGS     M.           SECS                      I
-----------------------------------------------------------------------
I TEMPERATURES DRY =  10.0 DEGR C.   BAROMETRIC PR. =1019.8MB   I
I              WET =       DEGR C.   TRANSPARENCY   =        M  I
-----------------------------------------------------------------------

                              | OBSERVED

TIME    DEP     TEMP    SAL     SIG-T     OXY   PO4    NH3   NO2    NO3   NO       SIO3  PH    TALK
 .0      0     7.573  30.321   23.67     9.12  0.37   01.1  0.26   00.0  914.2     7.     :     :
 .0      5     7.923  31.515   24.59     9.24  0.31   01.1  0.24   00.5  829.4     7.     :     :
 .0     15     6.440  32.329   25.43     8.67  1.37   03.3  0.35   00.0  774.1    16.     :     :
 .0     18     5.606  32.449   25.66     7.47  1.29   05.4  0.43    .              24.     :     :

                              STANDARD

        DEP     TEMP    SAL     SIG-T     OXY       SP VOL   DEL D
         0     7.57   30.321   23.67     9.12      424.06     .000
        10     7.44   32.046   25.11     9.96      287.11     .036
```

Table 2. Dissolved oxygen and nutrient data: DUT-01A

```
AC   CRUISE 251 CONSECUTIVE STATION NO.  56.   DUT002     11/ 6/78
------------------------------                             11.6 HOURS GMT

  LATITUDE = 53  52.2N   LONGITUDE = 166  31.2W   SONIC DEPTH =   30 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- ( ) ---NOT RECORDED        .
  CLOUD AMOUNT --- ( ) --- NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-------------------------------------------------------------------------
I           DIRECTION          SPEED                                    I
I WIND      135 - 144 DEGS     5 KNOTS                                  I
-------------------------------------------------------------------------
I           DIRECTION         HEIGHT       PERIOD                       I
I SEA        0 -    0 DEGR       0.          SECS                       I
I SWELL        -      DEGR       0.          SECS                       I
-------------------------------------------------------------------------
I TEMPERATURES -DRY =    9.7 DEGR C.   BAROMETRIC PR. =1019.2MB   I
I              -WET =        DEGR C.   TRANSPARENCY   =        M   I
-------------------------------------------------------------------------

                                 ;OBSERVED

TIME    DEP     TEMP     SAL     SIG-T      OXY   PO4    NH3   NO2    NO3    NO       SIO3  PH    TALK
10.0     0      7.924     .        . .      9.16  4.97   04.7  0.29    .              22.    .       .
10.0     5      7.634     .        .        9.44  0.39   01.1  0.27   00.0   944.6     6.    .       .
10.0    15      5.954     .        .        8.56  1.04   05.4  0.42   00.6   769.6    17.    .       .
10.0    25      4.964     .        .        4.64  3.43   24.6  0.58    1.6   430.4    64.    .       .

                                 STANDARD

        DEP     TEMP     SAL     SIG-T      OXY        SP VOL   DEL D
         0      7.92     . 0       .        9.16          .       .
        10      6.78     . 0       .        9.32          .       .
        20      5.15     . 0       .        6.92          .       .
```

Table 3. Dissolved oxygen and nutrient data: DUT-02

```
AC   CRUISE 251 CONSECUTIVE STATION NO.  57.   DUT000     11/ 6/78
-----------------------------------                        13.0 HOURS GMT

 LATITUDE = 53  53.5N   LONGITUDE = 166  30.0W   SONIC DEPTH =   34 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- ( ) ---NOT RECORDED        .
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
I          DIRECTION          SPEED                                   I
I WIND     1 5 - 196 DEGR    10 KNOTS                                 I
-----------------------------------------------------------------------
I          DIRECTION         HEIGHT         PERIOD                    I
I SEA        0 -    0 DEGR       M.             SECS                  I
I SWELL        -      DEGR       M.             SECS                  I
-----------------------------------------------------------------------
I TEMPERATURES -DRY =     7.2 DEGR C.   BAROMETRIC PR. =1018.3MB    I
I              -WET =         DEGR C.   TRANSPARENCY   =        M    I
-----------------------------------------------------------------------

                                   OBSERVED

TIME   DEP    TEMP     SAL    SIG-T    OXY   PO4   NH3   NO2   NO3    NO    SIO3  PH   TALK
11.6     0   7.743  34.537   26.99   9.10  0.31  01.5  0.25  00.0  312.4    6.   .      .
11.6     5   7.608  31.596   24.70   9.71  0.24  00.4  0.26  00.2  868.7   18.   .      .
11.6    15     .       .     38.87   9.03  0.06  33.2  7.03  00.0  306.2   1.3   .      .
11.6    30     .       .     38.86   6.41  1.93  11.6  0.55  00.7  578.6   40.   .      .

                                   STANDARD

       DEP    TEMP     SAL    SIG-T    OXY       SP VOL   DEL D
         0    7.74  34.537   26.99    9.10         .        .
```

Table 4. Dissolved oxygen and nutrient data: DUT-00

```
AC  CRUISE 261 CONSECUTIVE STATION NO.  59.   HEL001     11/ 6/78
-----------------------------                             15.0 HOURS GMT

 LATITUDE = 53  55.0N   LONGITUDE = 165  34.0W   SONIC DEPTH =   80 M

 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- (6) ---STRATOCUMULUS       .
 CLOUD AMOUNT --- (7) ---7/8           .
 VISIBILITY --- (7) ---10-20 KM
-------------------------------------------------------------------
I              DIRECTION          SPEED                             I
I  WIND        175 - 184 DEGS     10 KNOTS                          I
-------------------------------------------------------------------
I              DIRECTION          HEIGHT        PERIOD              I
I  SEA         175 - 184 DEGR     0.3 M.            SECS            I
I  SWELL          -       DEGR      M.              SECS            I
-------------------------------------------------------------------
I TEMPERATURES -DRY =     7.8 DEGR C.    BAROMETRIC PR. =1017.1MB   I
I              -WET =         DEGR C.    TRANSPARENCY   =         M I
-------------------------------------------------------------------

                                  OBSERVED

 TIME    DEP     TEMP     SAL      SIG-T      OXY    PO4     NH3   NO2    NO3     NO         SIO3  PH    TALK
 13.3     0      6.938   29.216   22.92      9.05   0.29    02.6  0.29    1.4   820.6       10.    .      .
 13.3     5      6.416   32.210   25.33      9.03   0.45    01.9  0.37   00.0   811.5       15.    .      .
 13.3    15      6.313   32.233   25.41      8.90   0.44    02.6  0.36   00.0   793.7       13.    .      .
 13.0    30      6.025   32.263   25.45      8.33   0.81    03.6  0.39    6.5   807.6       23.    .      .
 13.9    70      5.064   32.599   25.61      7.46   1.10    06.2  0.42   13.2   786.6       38.    .      .

                                  STANDARD

         DEP     TEMP     SAL      SIG-T      OXY          SP VOL   DEL D
          0      6.93    29.216   22.92      9.05         495.07     .000
         10      6.36    32.242   25.37      9.02         261.63     .038
         20      6.22    32.233   25.42      8.73         257.01     .064
         30      6.02    32.263   25.45      8.30         254.71     .089
         50      5.57    32.384   25.58      7.84         247.29     .139
```

Table 5. Dissolved oxygen and nutrient data: HEL-1

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  69,   HEL002     11/ 6/79
--------------------------------                          17.7 HOURS GMT

  LATITUDE = 51  54.6N   LONGITUDE = 166  33.5W   SONIC DEPTH =   14 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (6) ---STRATOCUMULUS       .
  CLOUD AMOUNT --- (8) ---8/8 TOTAL     .
  VISIBILITY --- (7) ---10-20 KM
-------------------------------------------------------------------
I           DIRECTION           SPEED                             I
I WIND      165 - 174 DEGR    15 KNOTS                            I
-------------------------------------------------------------------
I           DIRECTION         HEIGHT       PERIOD                 I
I SEA       165 - 174 DEGR   0.3 M.          SECS                 I
I SWELL        -      DEGR      M.           SECS                 I
-------------------------------------------------------------------
I TEMPERATURES -DRY =    7.8 DEGR C.   BAROMETRIC PR. =1015.6MB  I
I              -WET =        DEGR C.   TRANSPARENCY   =        M  I
-------------------------------------------------------------------

                                OBSERVED

 TIME    DEP     TEMP     SAL     SIG-T     OXY   PO4    NH3   NO2    NO3    HO       SIO3  PH    TALK
 15.9      0     7.494   29.864   23.34     8.83  0.48   01.1  0.25   00.9   795.4    18.     :       :
 15.9      5     6.798   32.016   25.14    10.14  0.12   01.1  0.21   00.3   909.8     9.     :       :

                                STANDARD

        DEP      TEMP     SAL     SIG-T     OXY        SP VOL   DEL D
          0      7.49    29.844   23.36     8.83          .        .
```

Table 6. Dissolved oxygen and nutrient data: HEL-2

```
VE   CRUISE 261 CONSECUTIVE STATION NO.  61.        03E     11/ 6/78
                                                             19.3 HOURS GMT
-----------------------------
  LATITUDE = 51  52.4N   LONGITUDE = 166  13.4W    SONIC DEPTH =    16 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (6) ---STRATOCUMULUS        .
  CLOUD AMOUNT --- (9) ---8/8 TOTAL      .
  VISIBILITY --- (7) ---10-20 KM
---------------------------------------------------------------------------
I          DIRECTION           SPEED                                       I
I WIND     135 - 144 DEGS    20 KNOTS                                      I
---------------------------------------------------------------------------
I          DIRECTION           HEIGHT        PERIOD                        I
I SEA        0 -   0 DEGS        0.            SECS                        I
I SWELL        -     DEGS         .            SECS                        I
---------------------------------------------------------------------------
I TEMPERATURES -DRY =    6.3 DEGS C.   BAROMETRIC PR. =1014.9MB            I
I              -WET =        DEGS C.   TRANSPARENCY   =        M           I
I
---------------------------------------------------------------------------
                              OBSERVED

 TIME   DEP    TEMP     SAL     SIG-T    OXY   PO4    NH3   NO2   NO3   NO     SIO3  PH   TALK
   .0    0      .     30.136     .      8.52  0.69   05.1  0.21  00.5  771.4   12.    .      .
   .0    5      .     32.116     .      8.74  0.81   06.0  0.26  01.3  792.0   14.    .      .

                              STANDARD

        DEP    TEMP     SAL     SIG-T    OXY        SP VOL   DEL D
         0       .3   01.340     .      8.52          .        .
```

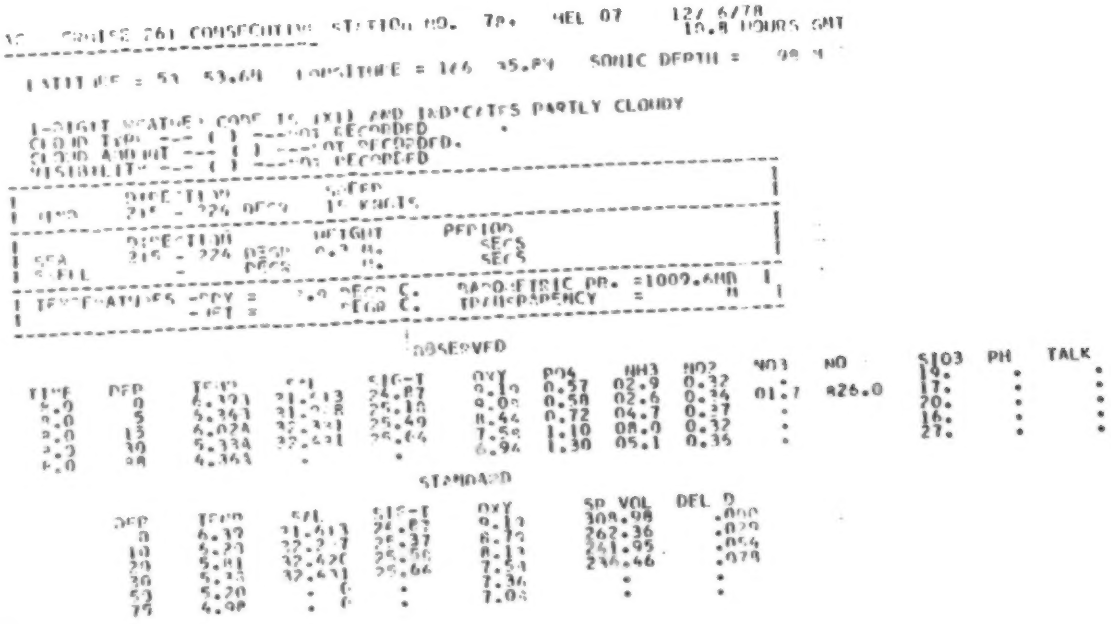
Table 7. Dissolved oxygen and nutrient data: 3E

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  71.   HEL03A    12/ 6/78
---------------------------                                2.9 HOURS GMT

 LATITUDE = 53  53.50   LONGITUDE = 166  33.2W   SONIC DEPTH =   40 M

 1-DIGIT WEATHER CODE IS (X/) AND INDICATES RAIN
 CLOUD TYPE --- (7) ---STRATUS
 CLOUD AMOUNT --- (3) ---4/8 TOTAL
 VISIBILITY --- (7) ---10-20 KM
-------------------------------------------------------------------
!          DIRECTION        SPEED                                  !
! WIND     165 - 174 DEGR   15 KNOTS                               !
-------------------------------------------------------------------
!          DIRECTION         HEIGHT      PERIOD                    !
! SEA      165 - 174 DEGR   0.2 M.         SECS                    !
! SWELL        -     DEGR      M.          SECS                    !
-------------------------------------------------------------------
! TEMPERATURES -DRY =  10.6 DEGR C.   BAROMETRIC PR. =1003.9MB   !
!              -WET =       DEGR C.   TRANSPARENCY   =        M   !
-------------------------------------------------------------------

                                   OBSERVED

 TIME    DEP     TEMP     SAL     SIG-T     OXY   PO4    NH3   NO2   NO3    IO      SIO3  PH   TALK
 19.3     0     7.273   30.502   23.69     9.47  0.25   01.8  0.23  00.4   849.1    13.    .     .
 19.3     5     7.154   30.740   24.11     9.62  0.35   00.7  0.23  00.4   773.2    13.    .     .
 19.3    15     6.098   32.201   25.45     8.61  1.50   05.4  0.31  03.5   600.2    19.    .     .
 19.3    27     5.208   32.411   25.68     7.23  1.02   08.0  0.43  10.8   744.5    32.    .     .

                                   STANDARD

         DEP     TEMP     SAL     SIG-T     OXY       SP VOL  DEL D
          0     7.27    30.502   23.69     9.47      402.04    .000
         10     6.67    31.526   24.77     8.62      312.28    .035
         20     5.46    32.328   25.55     8.22      244.96    .064
```

Table 8. Dissolved oxygen and nutrient data: HEL-3A

```
HC   CRUISE 261 CONSECUTIVE STATION NO.  74.   HEL 03     12/ 6/78
--------------------------------                              8.0 HOURS GMT

  LATITUDE = 53  53.7N   LONGITUDE = 166  34.3W   SONIC DEPTH =    49 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
!             DIRECTION          SPEED                                !
!  WIND     135 - 184 DEGR       ? KNOTS                              !
-----------------------------------------------------------------------
!             DIRECTION          HEIGHT       PERIOD                  !
!  SEA          0 -    0 DEGR       0.           SECS                 !
!  SWELL          -      DEGR       0.           SECS                 !
-----------------------------------------------------------------------
! TEMPERATURES -DRY =   10.4 DEGE C.    BAROMETRIC PR. =1008.0MB    !
!              -WET =        DEGE C.    TRANSPARENCY   =        M    !
-----------------------------------------------------------------------

                              OBSERVED

TIME    DEP      TEMP     SAL     SIG-T      OXY    PO4    NH3   NO2    NO3    HO      SIO3   PH    TALK
 2.6      0      7.143   30.540   24.21      9.42   0.24   02.2  0.24   00.6   346.4   12.     .      .
 2.8      5      6.259   32.263   25.45      9.83   0.71   03.3  0.30   02.5   310.8   17.     .      .
 2.3     15      5.517   32.354   25.56      7.77   1.10   06.5  0.39   07.9   254.8   25.     .      .
 2.8     30      5.234   32.445   25.76      7.46   1.16   09.0  0.42   11.2   266.9   32.     .      .
 2.8     40      5.064   32.412   25.82      7.32   1.30   05.4  0.42   13.4   274.1   38.     .      .

                              STANDARD

        DEP      TEMP     SAL     SIG-T      OXY          SP VOL   DEL D
          0      7.14    30.940   24.27      9.42         366.95    .000
         10      5.77    32.309   25.50      8.25         249.75    .031
         20      5.36    32.364   25.61      7.57         238.94    .055
         30      5.23    32.435   25.70      7.46         230.79    .079
```

Table 9. Dissolved oxygen and nutrient data: HEL-3



```
NC    CRUISE 261 CONSECUTIVE STATION NO.  78.   HEL 07     12/ 6/78
                                                            10.8 HOURS GMT
-------------------------------
  LATITUDE = 53  53.6N   LONGITUDE = 166  35.8W   SONIC DEPTH =   98 M

  1-DIGIT WEATHER CODE IS (X)) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- ( ) ---NOT RECORDED
  CLOUD AMOUNT --- ( ) ---NOT RECORDED.
  VISIBILITY --- ( ) ---NOT RECORDED
-----------------------------------------------------------------------
|          DIRECTION          SPEED                                    |
| WIND     21? - 224 DEGS     1? KNOTS                                 |
-----------------------------------------------------------------------
|          DIRECTION          HEIGHT        PERIOD                     |
| SEA      215 - 224 DEGS     0.? M.          SECS                     |
| SWELL        -     DEGS        M.           SECS                     |
-----------------------------------------------------------------------
| TEMPERATURES -DRY =    ?.9 DEGR C.   BAROMETRIC PR. =1009.6MB   |
|              -WET =        DEGR C.   TRANSPARENCY   =       M   |
-----------------------------------------------------------------------
                              OBSERVED

 TIME   DEP   TEMP    SAL     SIG-T   OXY   PO4   NH3   NO2   NO3   NO     SIO3  PH  TALK
  ?.0    0    6.321  31.613   24.87   9.19  0.57  02.9  0.32   .           19.    .    .
  ?.0    5    5.361  31.??8   25.10   9.09  0.58  02.6  0.34  01.7  826.0  17.    .    .
  ?.0   13    6.028  32.341   25.49   8.44  0.72  04.7  0.37   .           20.    .    .
  ?.0   30    5.334  32.431   25.64   7.59  1.10  08.0  0.32   .           16.    .    .
  ?.0   98    4.363    .        .     6.94  1.30  05.1  0.35   .           27.    .    .
                              STANDARD

        DEP   TEMP    SAL     SIG-T   OXY        SP VOL   DEL D
         0    6.32   31.613   24.87   9.19       308.98    .000
        10    5.29   32.2?7   25.37   8.79       262.36    .029
        20    5.81   32.420   25.56   8.13       241.95    .054
        30    5.33   32.431   25.64   7.54       236.46    .078
        50    5.20     .  0     .     7.36          .        .
        75    4.98     .  0     .     7.08          .        .
```

Table 10. Dissolved oxygen and nutrient data: HEL-7

```
TC   CRUISE 261 CONSECUTIVE STATION NO.  82,   HEL 06      12/ 6/78
-------------------------------                              15.4 HOURS GMT

  LATITUDE = 51  55.28   LONGITUDE = 166  35.91   SONIC DEPTH =  132 M

  1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
  CLOUD TYPE --- (7) ---STRATUS
  CLOUD AMOUNT --- (6) ---7/8
  VISIBILITY --- (7) ---10-20 KM
----------------------------------------------------------------------
I         DIRECTION          SPEED                                   I
I WIND        -       DEGS     KNOTS                                 I
----------------------------------------------------------------------
I         DIRECTION          HEIGHT      PERIOD                      I
I SEA       0 -    0 DEGS       M.          SECS                     I
I SWELL       -      DEGS       M.          SECS                     I
----------------------------------------------------------------------
I TEMPERATURES -DRY =     7.0 DEGS C.   BAROMETRIC PR. =1009.0MB   I
I              -WET =         DEGS C.   TRANSPARENCY   =        M   I
----------------------------------------------------------------------

                              OBSERVED

 TIME   DEP    TEMP    SAL     SIG-T     OXY   PO4    NH3   NO2    NO3    NO        SIO3  PH    TALK
 13.9    0    6.563  31.843   25.01     9.31  0.28   01.6  0.31    .                13.    .      .
 10.8    5    6.468  31.920   25.04     9.15  0.29   02.6  0.32    .                14.    .      .
 10.9   15      .       .       .       8.55  0.70   04.4  0.33    .                16.    .      .
 13.8   30      .    32.449     .       7.74  0.80     .   0.30    .                12.    .      .
 13.9   50    4.993  32.431   25.84     7.23  2.20   06.2  0.34    .                23.    .      .
 10.5   75    4.363  32.453   25.90     6.97  1.40   05.8  0.45    .                39.    .      .
 13.9  125    4.718  32.741   25.93     6.66  1.64   05.4  0.51    .                47.    .      .

                              STANDARD

        DEP    TEMP    SAL     SIG-T     OXY       SP VOL   DEL D
          0    6.55  31.843   25.03     9.31      293.77    .000
         10    6.38  31.962   25.15     9.07      283.17    .029
         20    5.56  32.101   25.34     8.25      261.31    .056
         30    5.61  32.445   25.64     7.74      236.11    .091
         50    4.93  32.431   25.84     7.23      217.42    .126
         75    4.94  32.453   25.90     6.97      212.33    .180
        100    4.77  32.733   25.95     6.75      207.78    .232
```

Table 11. Dissolved oxygen and nutrient data: HEL-6

```
AC   CRUISE 261 CONSECUTIVE STATION NO.  93.   HEL 04     13/ 6/78
------------------------------                               4.7 HOURS GMT

  LATITUDE = 51  53.2N   LONGITUDE = 166  34.4W   SONIC DEPTH =   95 M

  1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
  CLOUD TYPE --- (6) ---STRATOCUMULUS
  CLOUD AMOUNT --- (7) ---7/8
  VISIBILITY --- (7) ---10-20 KM
-------------------------------------------------------------------
I            DIRECTION          SPEED                              I
I WIND      205 - 214 DEGM       KNOTS                             I
-------------------------------------------------------------------
I           DIRECTION        HEIGHT      PERIOD                    I
I SEA         0 -    0 DEGM      M.         SECS                   I
I SWELL         -      DEGM      M.         SECS                   I
-------------------------------------------------------------------
I TEMPERATURES -DRY =  10.0 DEGS C.   BAROMETRIC PR. =1008.1MB    I
I              -WET =       DEGS C.   TRANSPARENCY    =       M   I
-------------------------------------------------------------------

                               OBSERVED

 TIME    DEP     TEMP    SAL     SIGMA-T   OXY   PO4    NH3   NO2   NO3    NO        SIO3  PH    TALK
 15.4     0     6.349  31.855   25.01     9.40  1.13   02.2  0.35    .                18.    .       .
 15.4    10     6.144  32.278   25.43     8.81  0.66   03.3  0.47    .                35.    .       .
 15.4    30     4.712  32.422   25.71     6.62  2.00   06.2  0.43  14.8   724.2       35.    .       .
 15.4    50     4.219  32.429   25.76     6.11  2.20   08.0  0.44  18.1   709.4       41.    .       .
 15.4    69     4.320  32.475   25.79     6.01  2.60   09.4  0.47  19.0   714.7       45.    .       .

                               STANDARD

         DEP     TEMP    SAL      SIG-T    OXY          SP VOL   DEL D
          0     6.34   31.855●  25.01     9.40         296.27     .000
         10     6.14   32.278   25.43     8.91         256.31     .029
         20     5.37   32.417   25.63     7.68         237.32     .052
         30     4.71   32.422   25.70     6.62         230.14     .076
         50     4.21   32.429   25.76     6.11         224.82     .121
         75     4.23   32.453   25.77     6.10         223.82     .177
```

Table 12. Dissolved oxygen and nutrient data: HEL-4

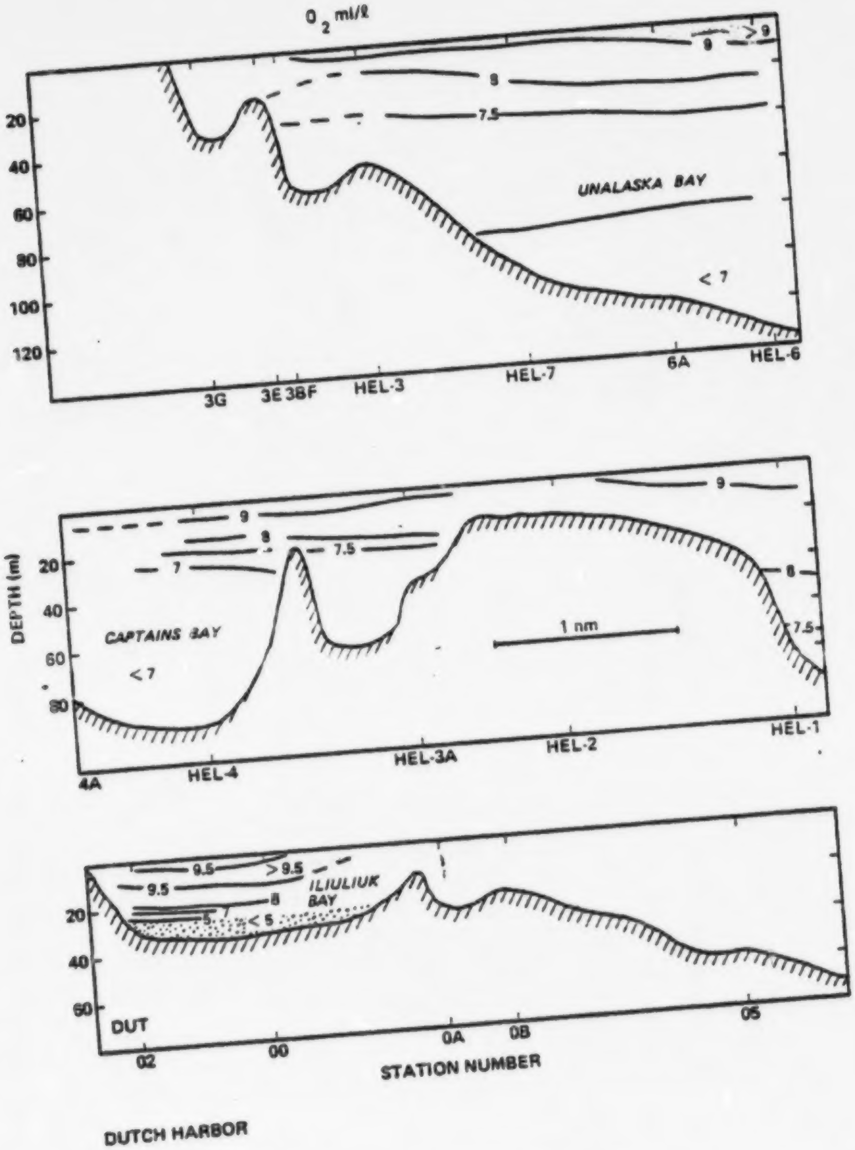


Figure 34. Longitudinal oxygen profiles.

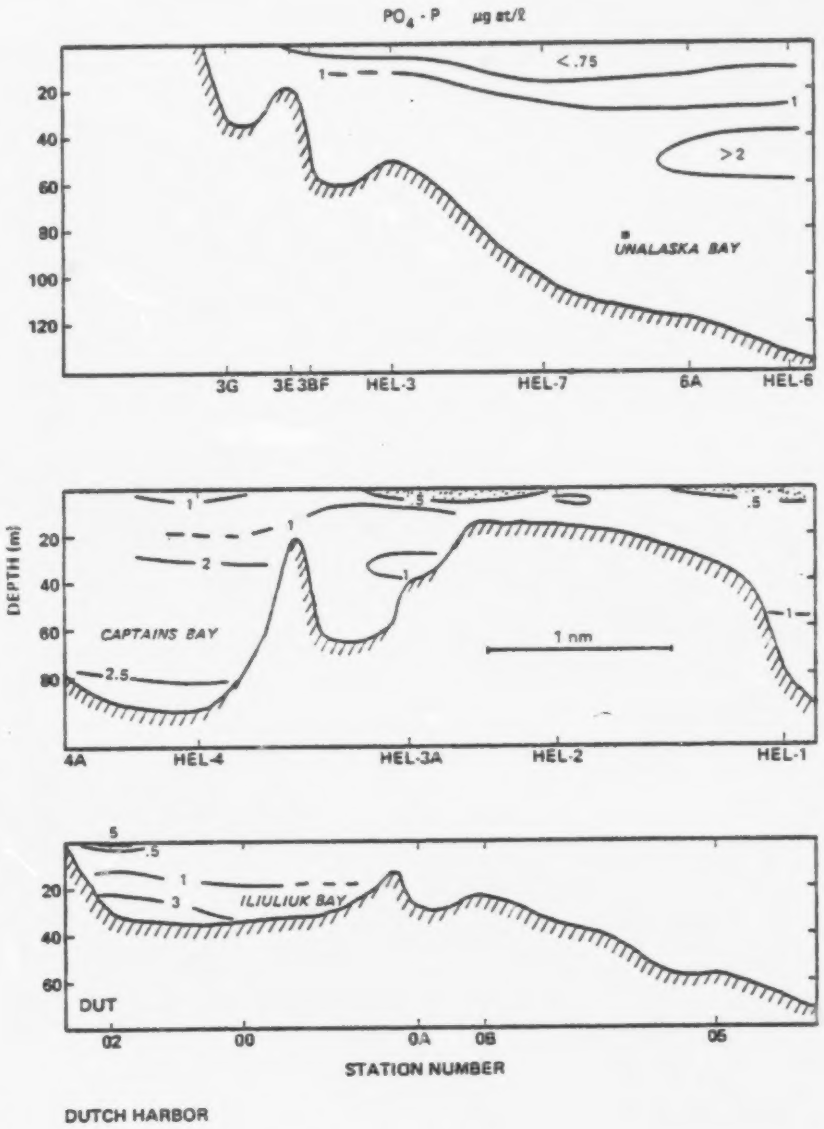


Figure 35. Longitudinal phosphate profiles.

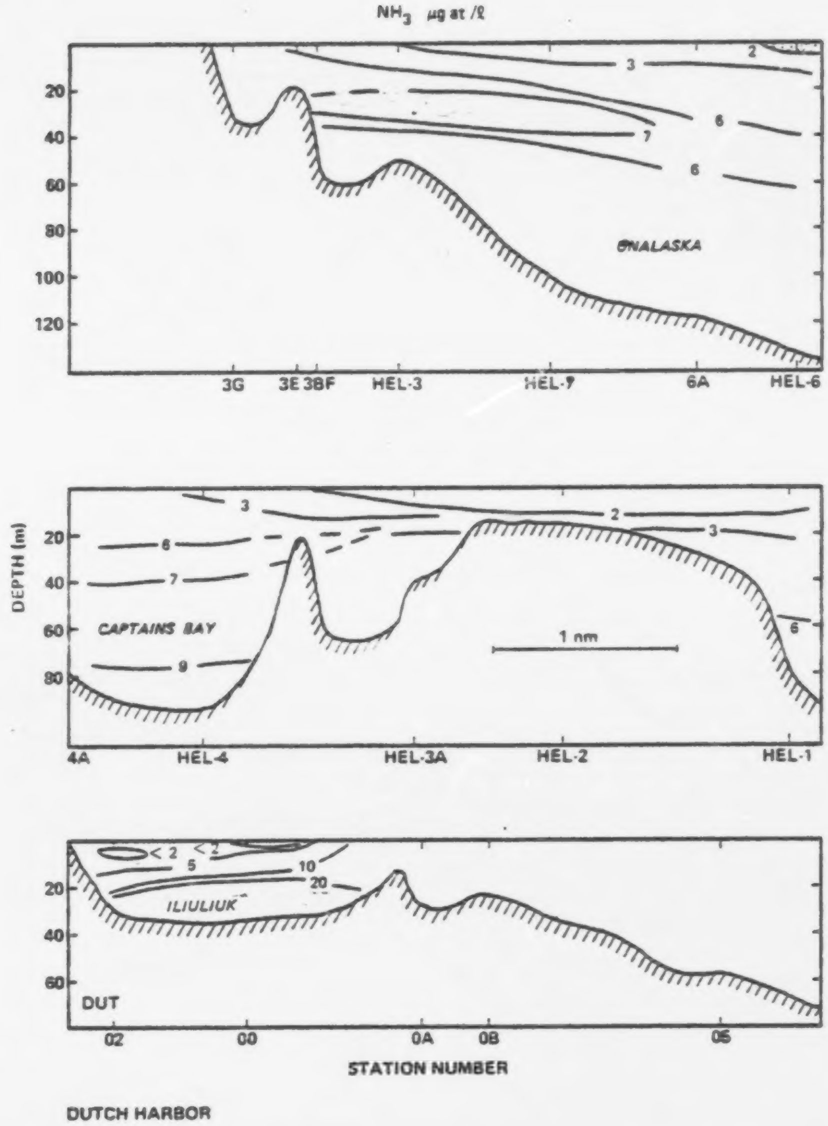


Figure 36. Longitudinal ammonia profiles.

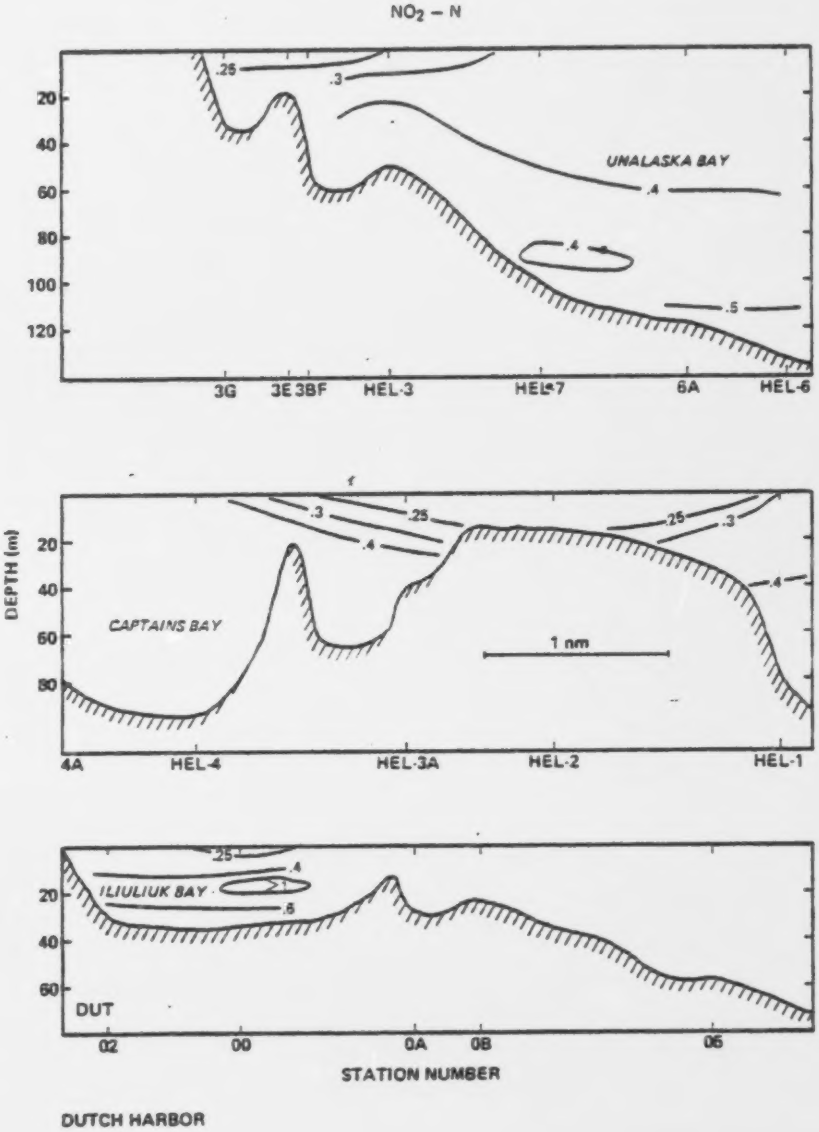


Figure 37. Longitudinal nitrite profiles.

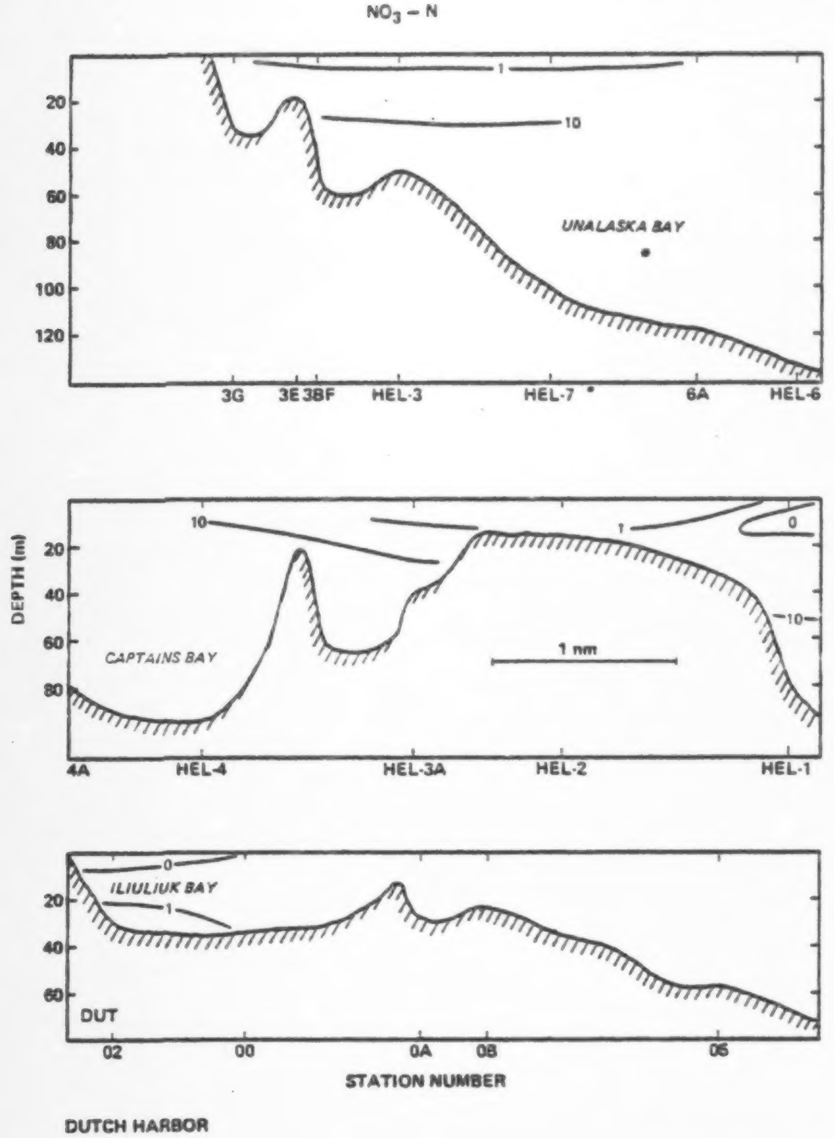


Figure 38. Longitudinal nitrate profiles.

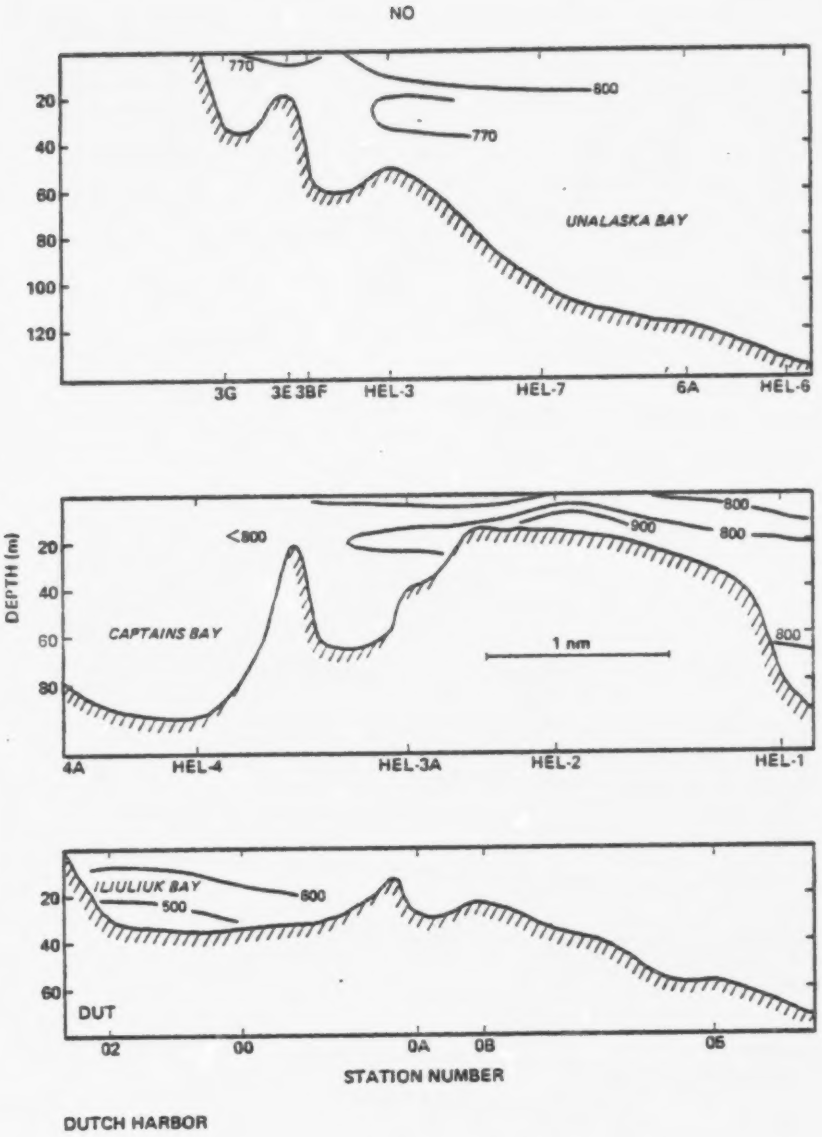


Figure 39. Longitudinal NO profiles.

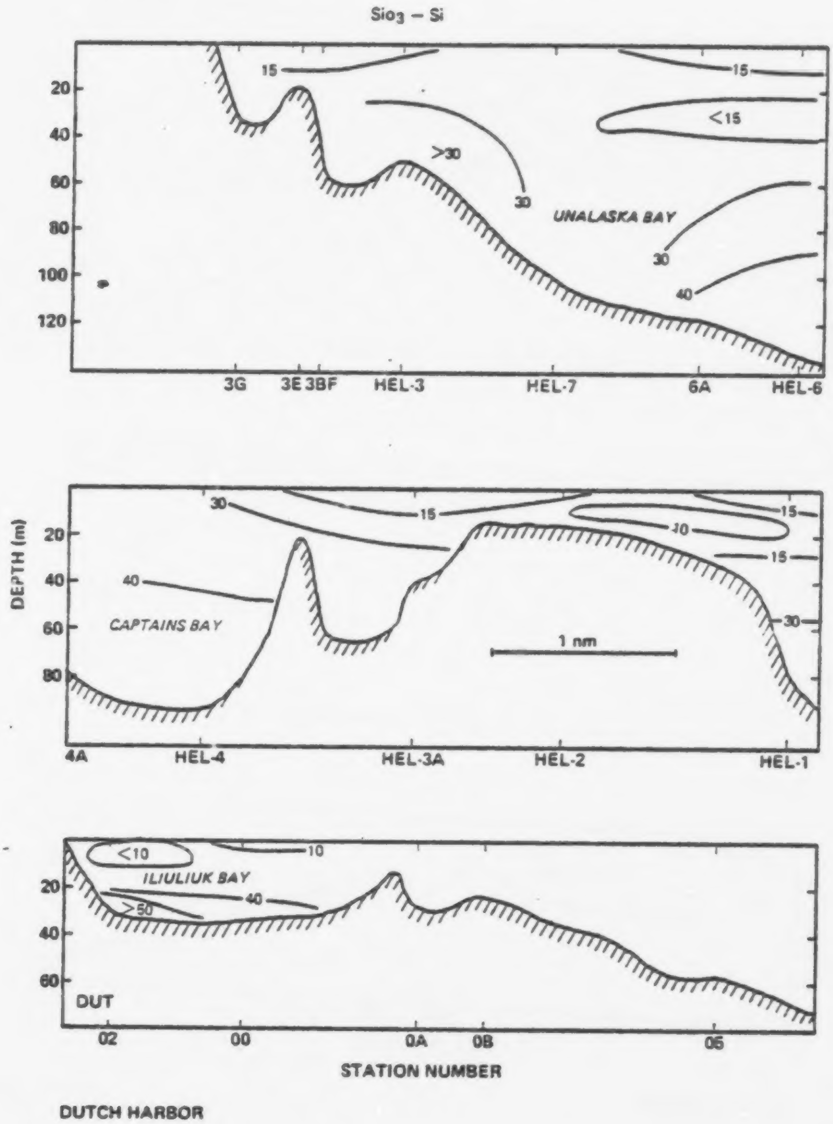


Figure 40. Longitudinal silicate profiles.

above) for dissolved oxygen, phosphate, the inorganic nitrogen species, computed NO and silicate respectively. Individual vertical station profiles are given as Figures 41-51. Sulfide analysis data are given as Table 13.

The principal sedimentological characteristics of the surficial sediments are listed in Tables 14 and 15. Figures 52 and 53 show the distributions of the (graphic) grain size means and the sorting indices (graphic standard deviations). Recent total organic carbon sediment contents are given in Figure 54.

DISCUSSION

Hydrography

In spite of the paucity of coverage certain hydrographic features are readily apparent. Figure 32 shows the water densities at this time of year to be well stratified: < 24 at the surface to > 26 at 120 m on the shelf, and lower surface densities, as would be expected, at the surface in the inlets. It is apparent also that the two restricted basins - Dutch Harbor and Captains Bay - are not in free exchange with adjacent shelf waters. Bottom waters within these basins are colder, and hence denser, than at corresponding shelf depths. Other factors being equal, it would be expected that summer surface stratification would maintain the apparent isolation of these basin waters, and this appears to be the case. In October 1977 - i.e. towards the end of the summer period - Colonell and Reeburgh (1978) have shown densities at 30 m at DUT-00 and HEL-1 to be 25.79 and 25.21 respectively; the corresponding June difference from the data presented here is 0.28. These values are cited here only as a rough guide since this is a dynamic nearshore environment and the profiles given have not been time averaged for tidal effects etc. Figure 33, for example, illustrates temperature and salinity profiles at two of these stations taken on different days and at different times and is illustrative of the sort of variation expected in the surface waters. Nevertheless from the little evidence presently available to us, it seems probable that the bottom waters of these basins are not advectively renewed through the summer. Colonell and Reeburgh (*op cit*) have noted that the prevailing summer winds here are northerly so that upwelling of denser water would not be expected at

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*Note: Continuation of text on page 88

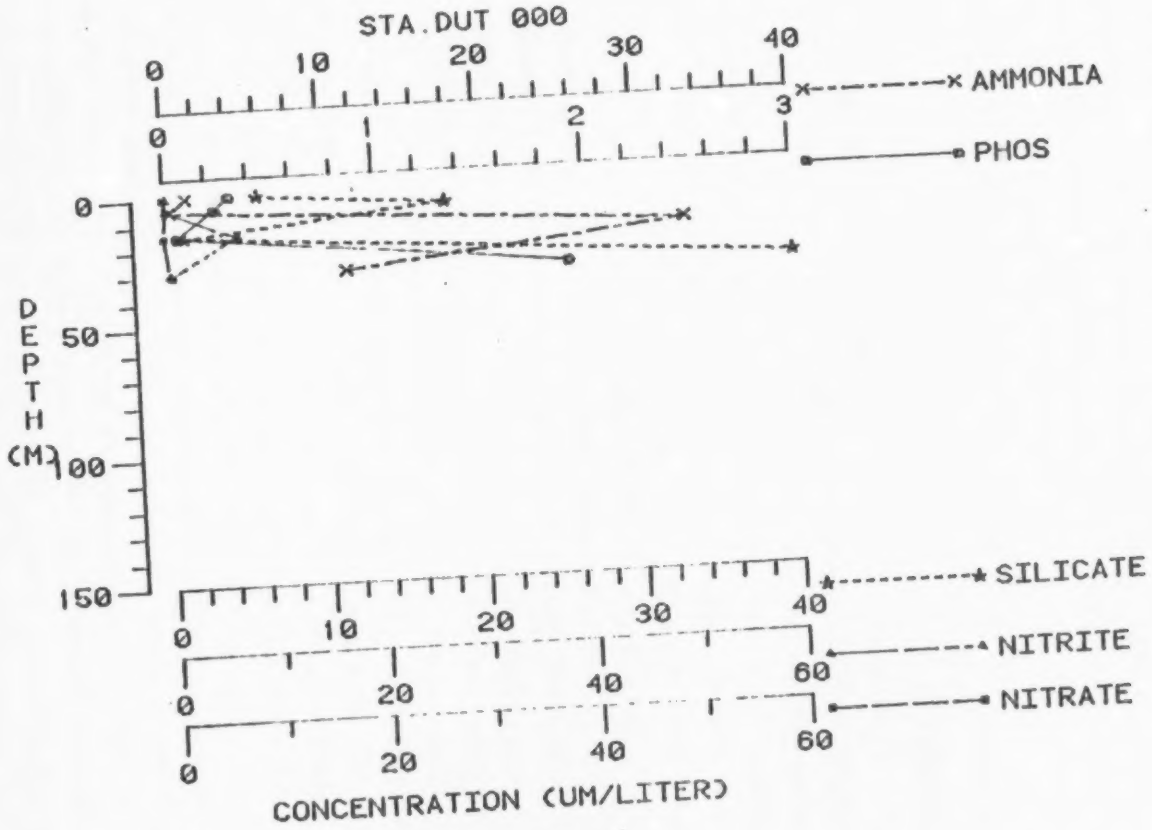


Figure 41. Vertical nutrient profiles: DUT-00.

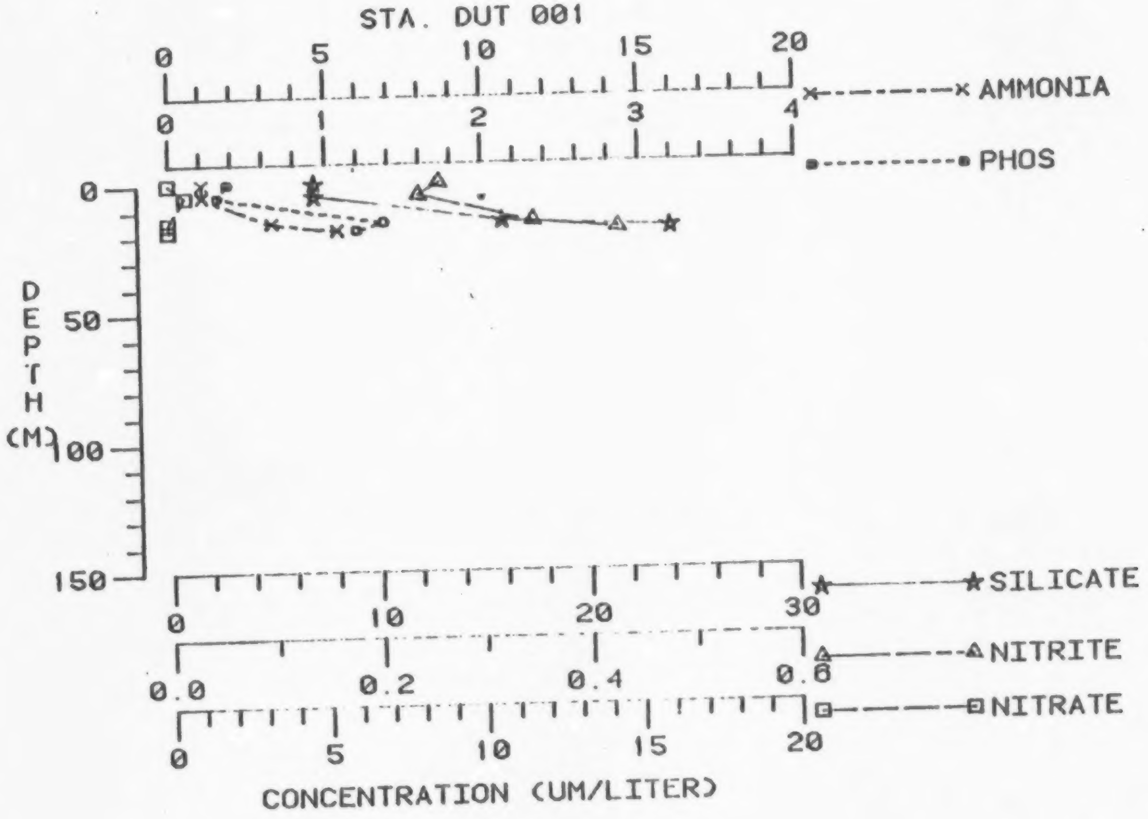


Figure 42. Vertical nutrient profiles: DUT-01A.

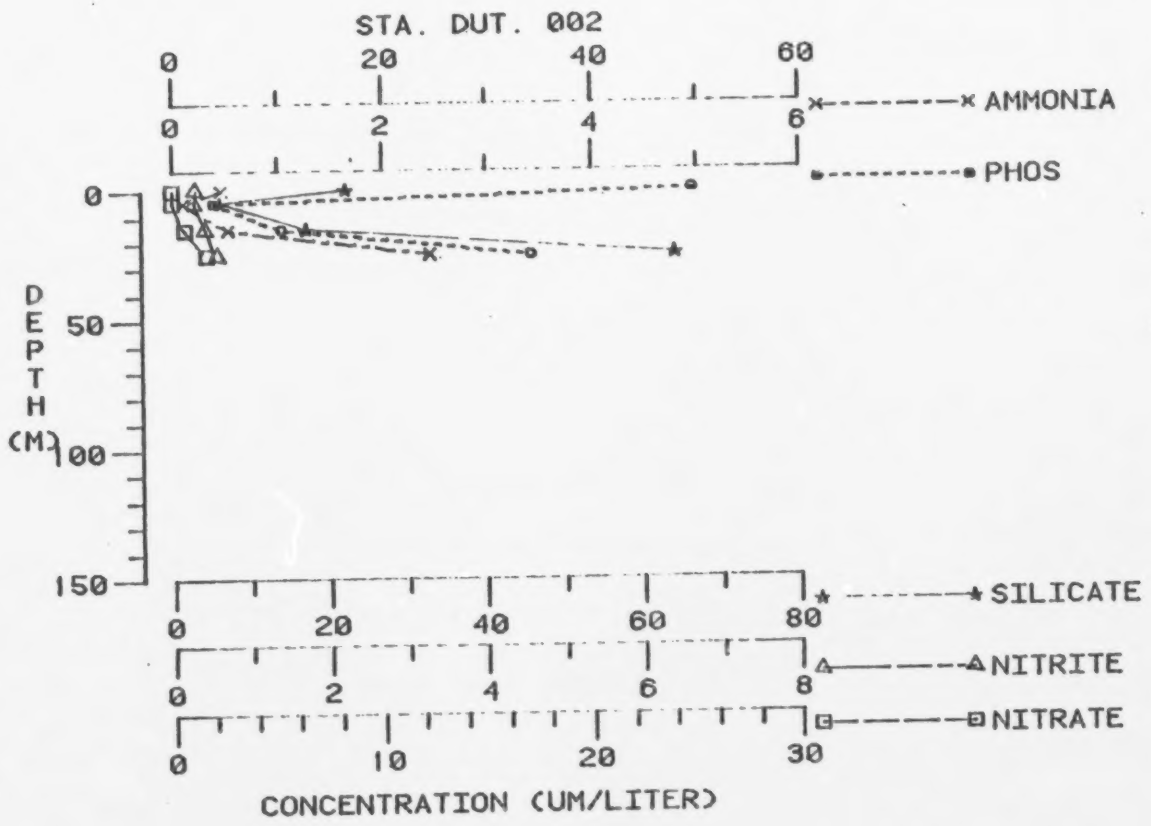


Figure 43. Vertical nutrient profiles: DUT-02.

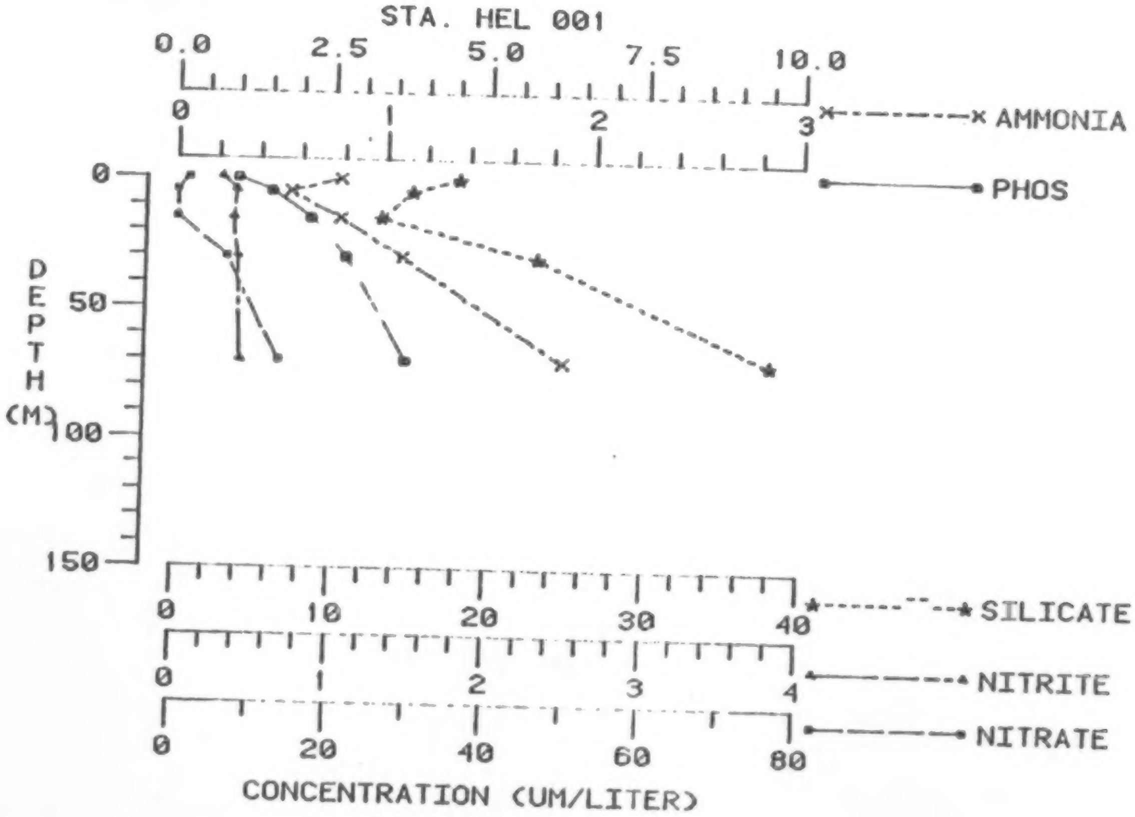


Figure 44. Vertical nutrient profiles: HEL-1.

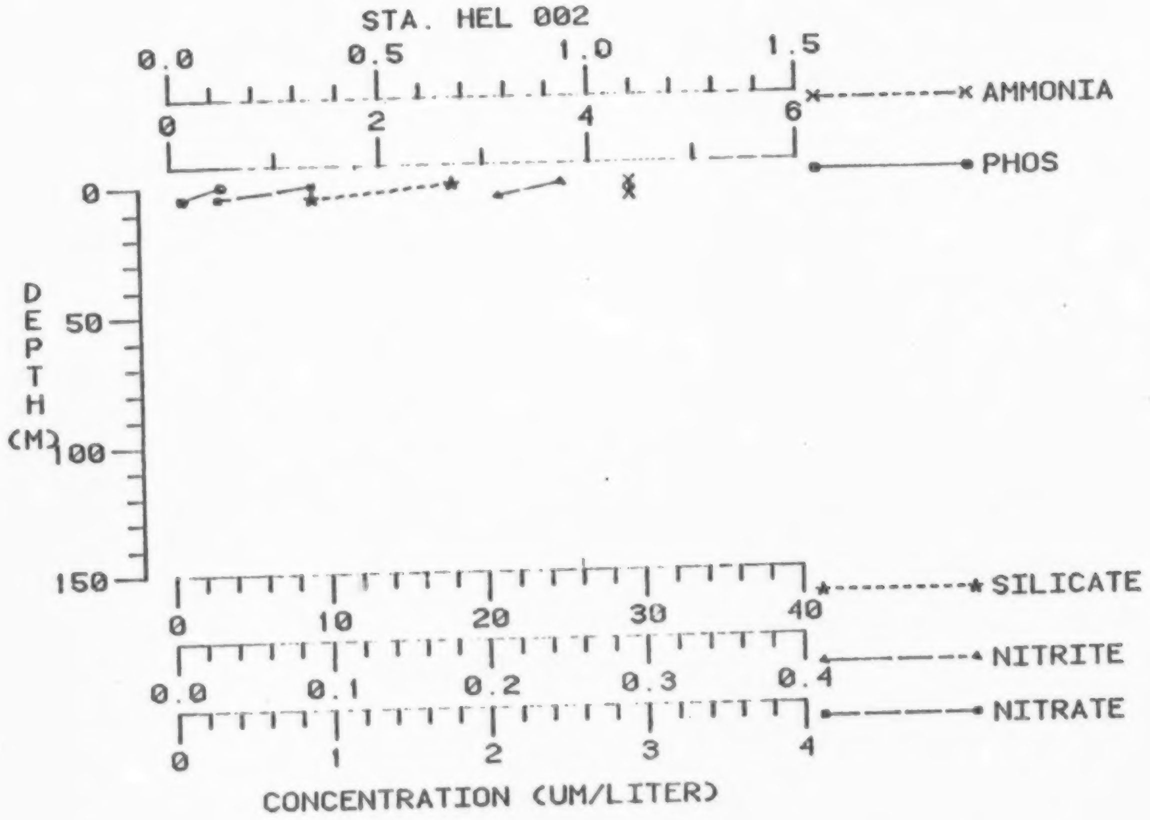


Figure 45. Vertical nutrient profiles: HEL-2.

0

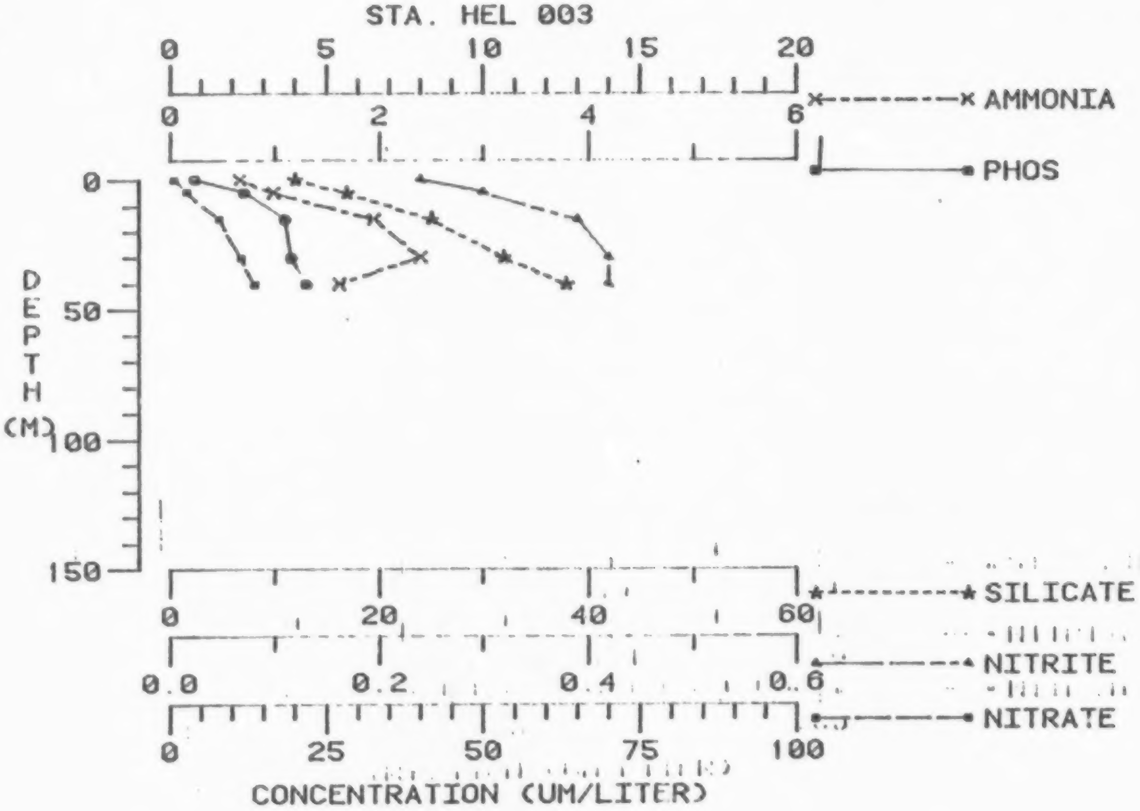


Figure 46. Vertical nutrient profiles: HEL-3.

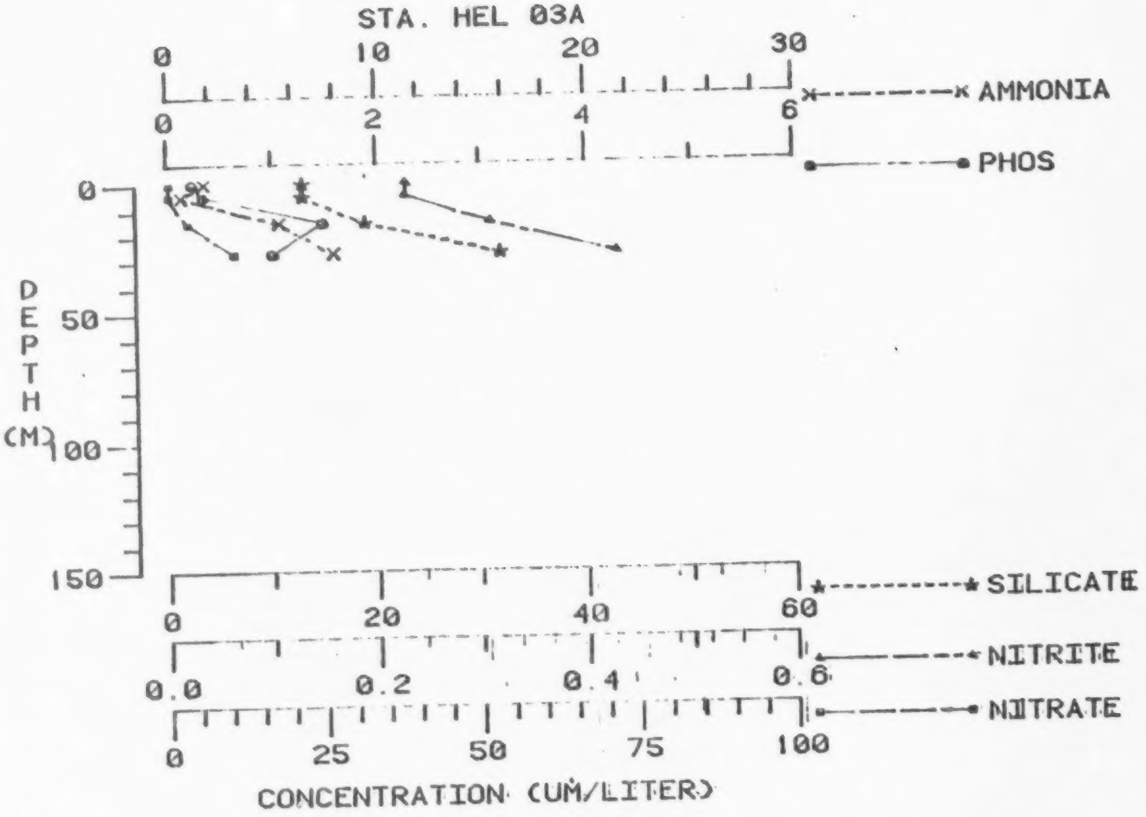


Figure 47. Vertical nutrient profiles: HEL-3A.

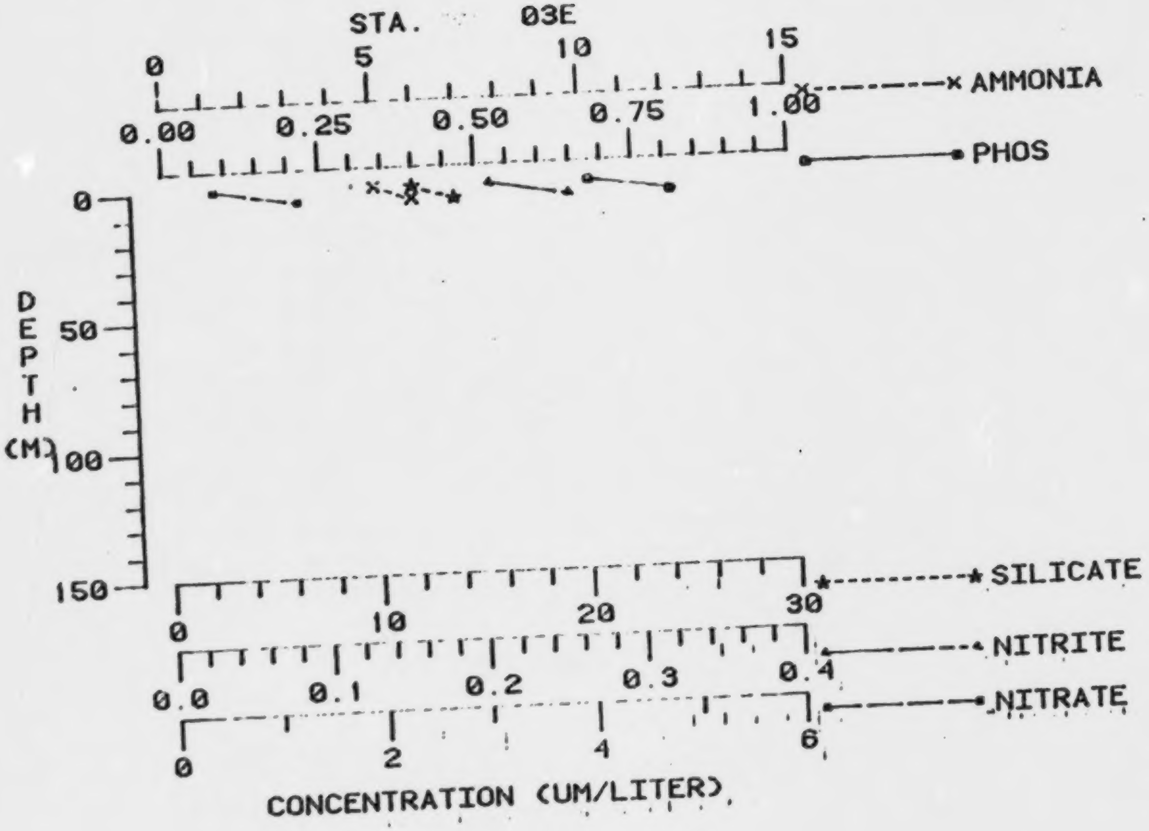


Figure 48. Vertical nutrient profiles: 3E.

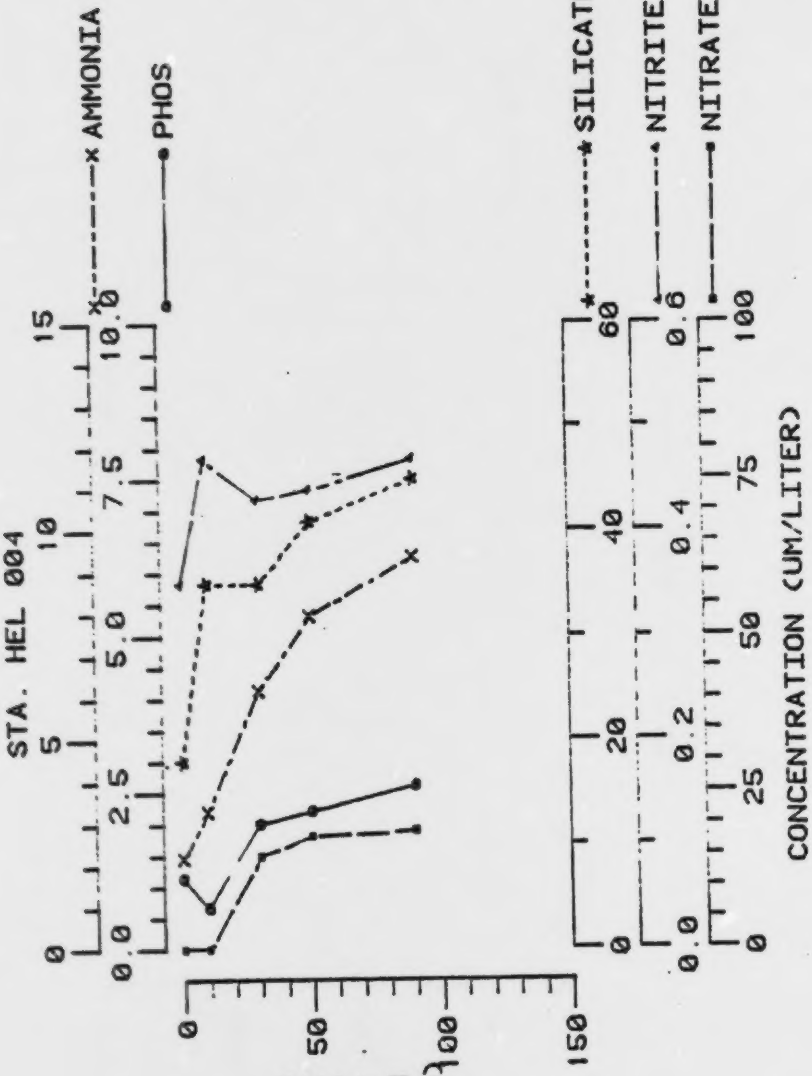


Figure 49. Vertical nutrient profiles: HEL-4.

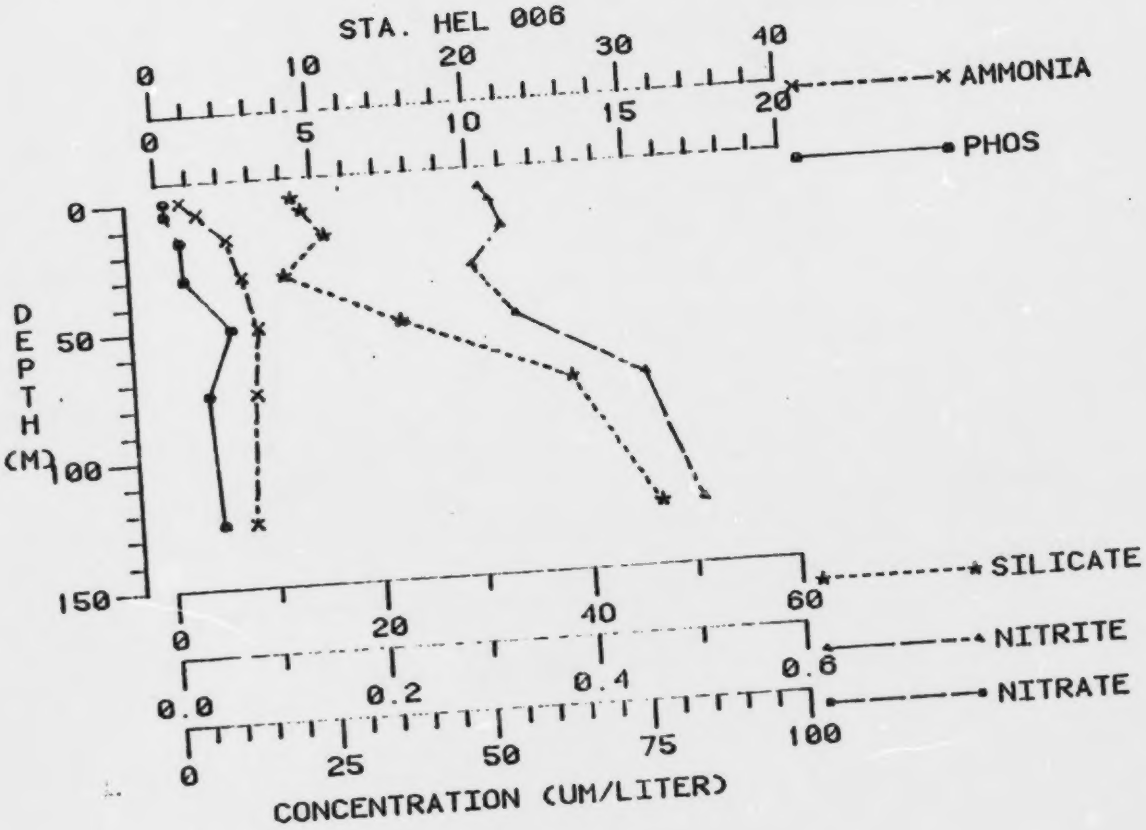


Figure 50. Vertical nutrient profiles: HEL-6.

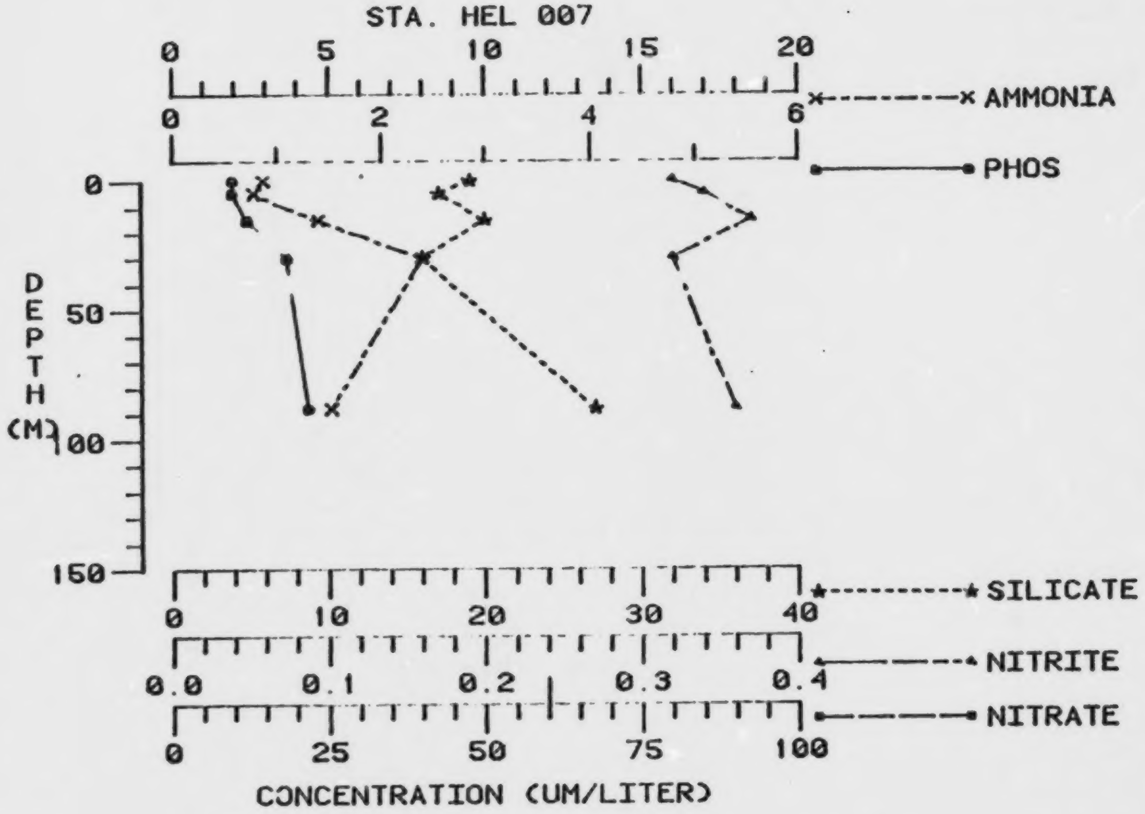


Figure 51. Vertical nutrient profiles: HEL-7.

TABLE 13. WATER COLUMN CHEMISTRY: TOTAL SOLUBLE SULFIDE CONCENTRATION (μg at/ℓ)

Station No.	Sample Depth (m)	Sulfide
DUT 00	27[1]	0.0
	34	0.0
HEL 1	67	0.0
	80	0.0
3H	29	0.0
	34	0.0
3AG	35	0.0
	38	0.0
3G	24	0.0
	31	0.0
3BF	51	0.0
	58	0.0
3DE	21	4.4
	26	12.4
HEL 4	95	0.0

[1] Two samples taken on station; ship not anchored at station.

TABLE 14. SEDIMENT GRAIN SIZE PARAMETERS

Station	Depth (m)	% Sand[a] (weight)	% Mud (weight)	Mean[b] (ϕ)	Standard Deviation[c] (ϕ)	Skewness[d]
DUT 0A	29	27.3	72.7	6.2	3.2	+0.58
DUT 0B	22	99.0	1.0	2.8	0.4	+0.06
DUT 02A	28	23.7	76.3	7.3	3.8	+0.12
1A	46	95.7	4.3	2.2	0.8	-0.07
HEL 3	49	70.4	29.6	3.5	2.4	+0.44
HEL 3A	40	88.8	11.2	2.9	1.7	+0.36
3B	51	70.3	29.7	4.0	2.5	+0.65
3AG	38	51.6	48.4	4.4	2.0	+0.67
3BF	58	36.2	63.8	6.0	3.2	+0.56
3C1	48	85.7	14.3	2.9	1.7	+0.29
3DE	26	80.2	19.8	3.1	2.2	+0.43
3E	16	72.3	27.7	3.7	2.6	+0.65
3G	31	52.8	47.2	5.0	2.9	+0.71
3H	34	17.1	82.9	6.6	3.2	+0.41
3I	32	89.5	10.5	2.9	0.9	+0.12
HEL 6	132	13.2	86.8	6.3	2.8	+0.60

a - sand < 1 mm; see text
b - graphic mean M_z
c - graphic standard deviation σ_I
d - inclusive graphic skewness Sk_I

TABLE 15. SEDIMENT TEXTURE

Station	Sorting	Skewness
DUT OA	very poorly sorted	strongly fine skewed
DUT OB	well sorted	near symmetrical
DUT O2A	very poorly sorted	fine skewed
1A	moderately sorted	near symmetrical
HEL 3	very poorly sorted	strongly fine skewed
HEL 3A	poorly sorted	strongly fine skewed
3B	very poorly sorted	strongly fine skewed
3AG	poorly sorted	strongly fine skewed
3BF	very poorly sorted	strongly fine skewed
3C1	poorly sorted	fine skewed
3DE	very poorly sorted	strongly fine skewed
3E	very poorly sorted	strongly fine skewed
3G	very poorly sorted	strongly fine skewed
3H	very poorly sorted	strongly fine skewed
3I	moderately sorted	fine skewed
HEL 6	very poorly sorted	strongly fine skewed

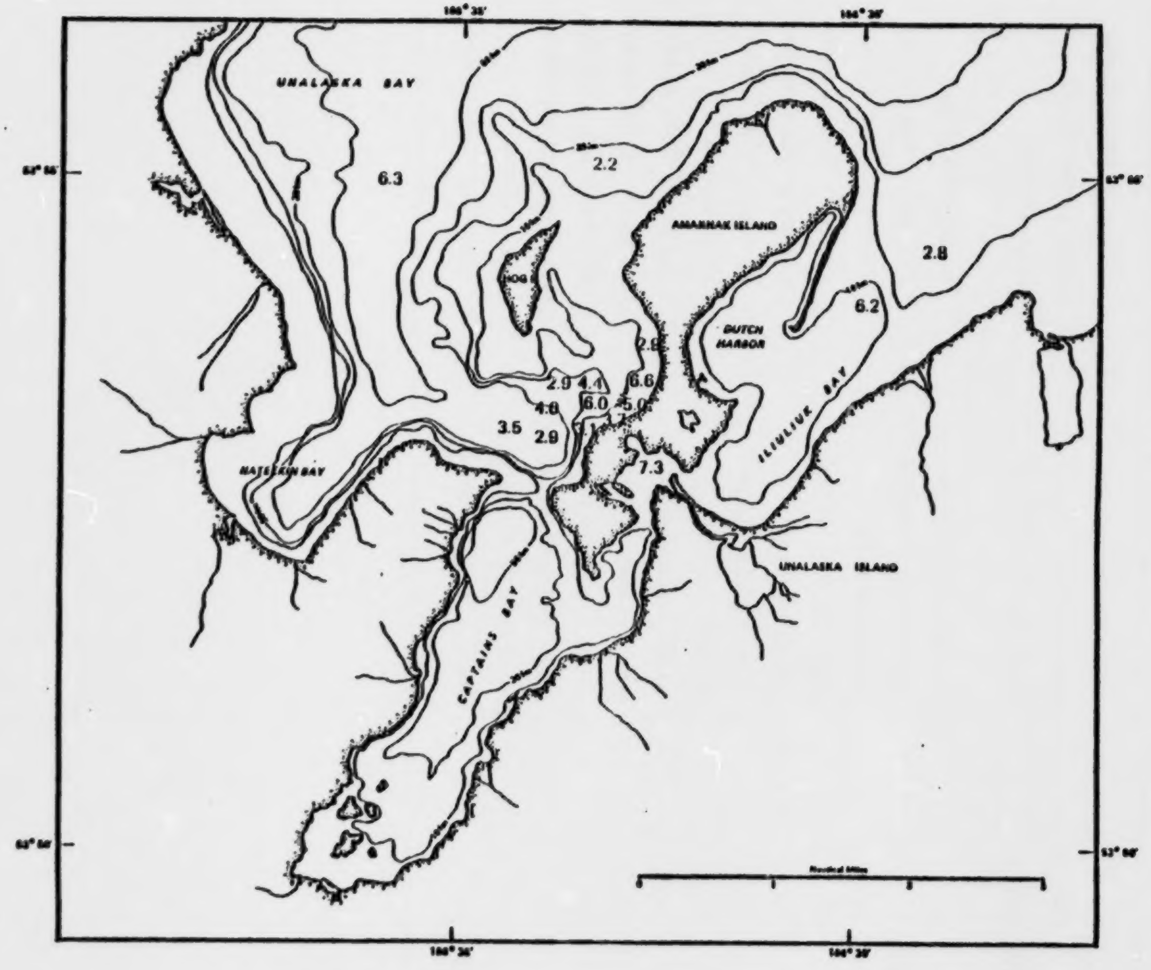

166° 35'
166° 30'
53° 55'
53° 50'
UNALASKA BAY
6.3
2.2
AMAKNAK ISLAND
2.8
6.2
DUTCH HARBOR
ILIULIUK BAY
HOG
2.9
4.4
6.6
4.8
6.0
5.0
3.5
2.9
7.3
NATEEKIN BAY
UNALASKA ISLAND
CAPTAINS BAY
Nautical Miles
0
1
2
3

Figure 52. Grain size mean distributions of surficial sediments < 1mm (Ø).

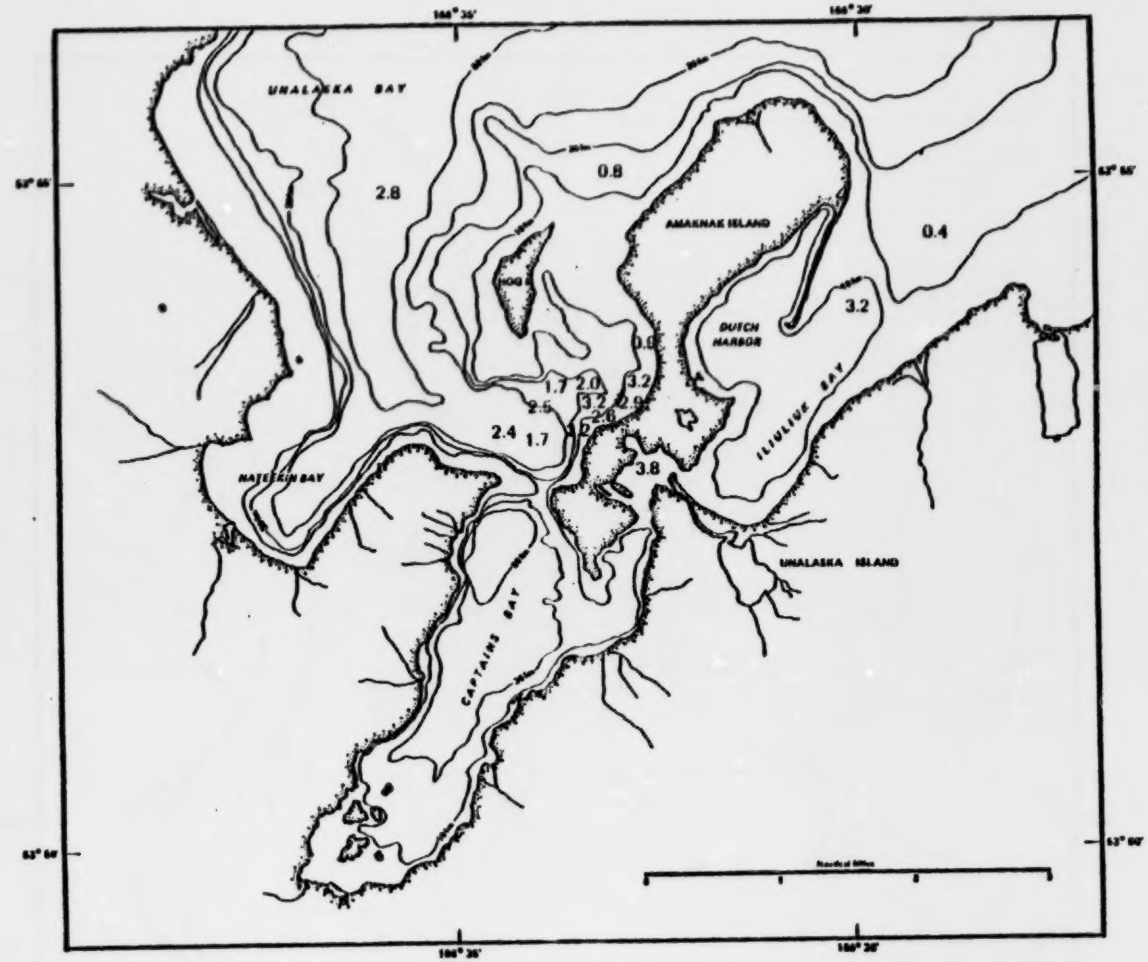

UNALASKA BAY
2.8
0.8
HOG
AMAKNAK ISLAND
0.4
DUTCH HARBOR
3.2
0.8
1.7
2.0
3.2
3.2
2.9
2.5
2.6
2
2.4
1.7
3.8
ILIULIUK BAY
NATEEKIN BAY
CAPTAINS BAY
UNALASKA ISLAND

Figure 53. Grain size standard deviation (sorting) distributions of surficial sediments < 1mm (Ø).

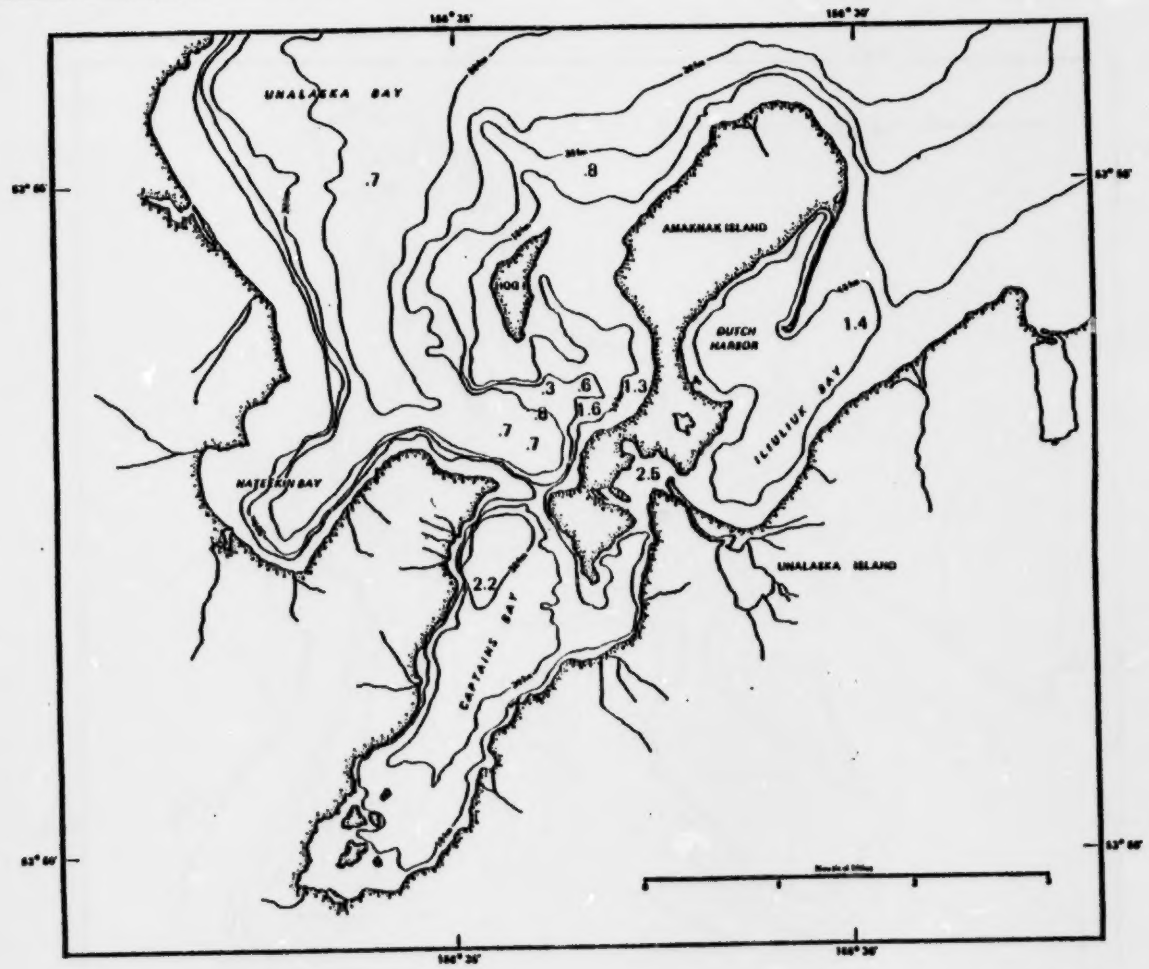

UNALASKA BAY
.7
.8
AMAKNAK ISLAND
HOG
DUTCH HARBOR
1.4
ILIULIUK BAY
.3
.6
1.3
.8
1.6
.7
.7
2.5
NATEEKIN BAY
2.2
CAPTAINS BAY
UNALASKA ISLAND

Figure 54. Organic carbon contents of surficial sediment (%).

this time. (The effects of tidal mixing are totally unknown.) No winter observations are presently available so the sequence of post-summer flushing events is not known.

Water Chemistry

At this time of year (June), oxygen values at the bottom of Captains Bay are somewhat lower than on the corresponding shelf, but not markedly so. Within Dutch Harbor proper, bottom oxygen is < 5 ml/ℓ. At this level benthic epifauna and pelagic organisms should not be adversely affected, neither should nitrate reduction occur in the column. However as oxygen consumption continues through the summer without basin water replenishment, near bottom anoxic conditions result: Colonell and Reeburgh (*op cit*) demonstrate this for the previous October. It should not be an impossible task to compute an order of magnitude carbon mass balance model, assuming stagnant conditions, to determine the relative importance of dumped carbon waste to natural run-off and column productivity in this scheme, but such data are not available to us at present.

Given the June oxygen distributions, there was no likelihood of other than a localized occurrence of water column sulfide, and such proved to be the case. The stations at which analyses for dissolved sulfide were made are shown in Table 13. Sulfide was present at one station only: 3DE showed 12.4 μg at/ℓ at 26 m and 4.4 μg at/ℓ five meters higher. (Fig. 55 is intended to show the approximate locations of this station in relation to the other parameters presented, but the represented bottom configuration is, as noted above, somewhat misleading here and the station is not quite on the profile line.) This locality is adjacent to a major processing waste outfall site (Universal Seafood Outfall). Although clearly an isolated phenomenon, such anoxia demonstrates that the carbon waste here is not rapidly dispersed and that mixing is slow in relation to the rate of production and release of sulfide at the sediment surface.

NO_3-N is depleted at the surface through this area and is, in fact, essentially absent at the surface of Dutch Harbor. At the time of year sampled (June) it may be assumed that the spring bloom has come and gone. Decomposition products are present at depth but the marked gradients in all the nitrogen species well demonstrate the stable stratification of the water. The

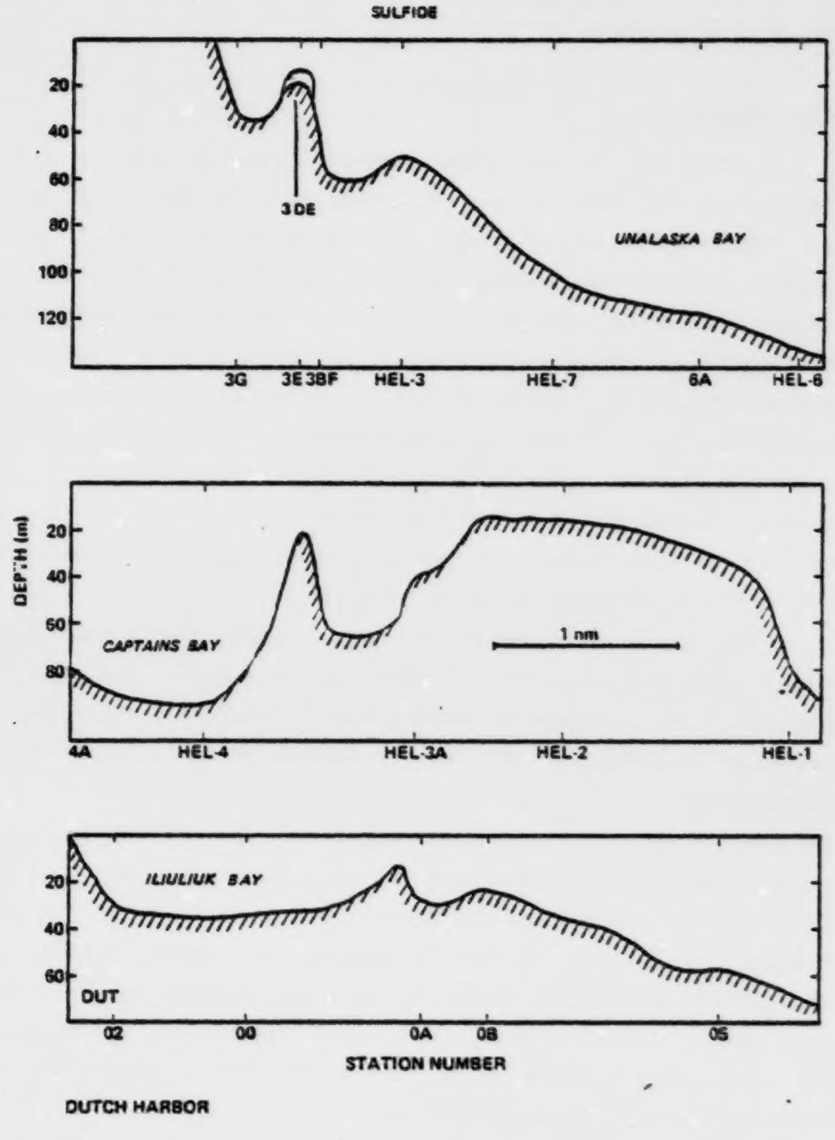


Figure 55. Longitudinal sulfide distribution.

phosphate and ammonia distributions shown in Figures 35 and 36 are of some interest. As in all shallow water, high organic lead regions, it may be presumed that major regeneration occurs at the sediment although, in general, the site of decomposition makes no difference to the mass balance. Table 16 attempts to compare the relative distribution of inorganic nitrogen and phosphate in the surface waters of "shelf stations" (HEL-1, -3, -6) and adjacent to the bottom within Captains Bay and Dutch Harbor (see Figs. 43 and 49). Data from June 1967 (Brickell and Goering, 1970), October 1977 (Colonell and Reeburgh, *op cit*) and from June 1978 (this study) are given. A N/P ratio of around 16 conforms with the classic Redfield expression. (We have combined ammonia, NO_3-N as being simple additive regeneration-nitrification products.) The low ratio values for the near bottom waters of Dutch Harbor may signify a better fit by an "anoxic model" having N/P closer to 8 as advocated by Suess (1976). However we favor enhanced bottom water concentrations of phosphate as signalling a significant flux from the sediments which are anoxic to very close to the benthic boundary. This phenomenon, basically related to the mobility of ferrous ions, has been discussed by many people (e.g. Taft and Taylor, 1976). Regardless of the nutrient sources these waters, once mixed back into the upper layers, must support considerable productivity. Given the overall dissolved oxygen concentrations at this time of year, the significant NO_2-N concentrations (Fig. 37) may be taken as an intermediary nitrification product rather than an indication of nitrate reduction in the column.

The June 1978 data for nutrients and oxygen are remarkably similar to values obtained for June ten years earlier by Brickell and Goering (1970). Changing seafood waste dispersal patterns over this decade are not known to us in detail, but it seems likely that, within Dutch Harbor proper, depletion of oxygen in the basin through the summer, leading to near-bottom fall anoxic conditions, is a natural annual phenomenon. Needless to say, any additional anthropogenic organic loading must increase the oxygen consumption rate and result in longer periods of anoxic water prior to the winter flushing.

TABLE 16. SUMMER DISTRIBUTION OF NUTRIENTS IN SURFACE SHELF WATERS (STATIONS HEL-1, -3, and -6) AND BOTTOM BASIN WATERS (STATIONS HEL-4 AND DUT-02)

μg at/ℓ; oxygen: ml/ℓ

A. June 1967 (Brickell and Goering, 1968)

Station	HEL-4	DUT-02
Depth	Bottom	Bottom
NH_3-N	1.6	23.8
NO_3-N	20.9	9.2
Total N	22.1	33.3
PO_4-P	2.5	5.0
N/P	9.0	7.8
Oxygen	5.6	4.3

B. October 1977 (Colonell and Reeburgh, 1978)

Station	HEL-1	HEL-6	HEL-4	DUT-02
Depth	Surface	Surface	Bottom	Bottom
NH_3-N	1.2	1.5	4.5	20.0
NO_3-N	12.5	13.0	35.8	1.0
Total N	14.1	14.9	40.6	21.1
PO_4-P	1.2	1.2	3.3	6.0
N/P	12.0	12.1	12.3	3.5
Oxygen	-	-	2.5	∿ 0

A. June 1978 (This study)

Station	HEL-1	HEL-3	HEL-4	DUT-02
Depth	Surface	Surface	Bottom	Bottom
NH_3-N	2.6	2.2	9.4	24.6
NO_3-N	1.4	0.6	19.0	1.6
Total	4.3	3.0	28.9	26.8
PO_4-P	0.3	0.2	2.6	3.4
N/P	14.4	12.9	11.1	7.8
Oxygen	-	-	6.1	4.7

Geology

Sediment from within the Dutch Harbor-Iliuliuk Bay basin and also from the floor of Unalaska Bay, is fine-grain (mean > 6 ϕ; Fig. 52) and poorly sorted (Fig. 53). Only small bottom currents would be expected at the benthic boundary within the confined basins and the sediment character is that of a "quiet" environment. We have insufficient information to consider the near-bottom conditons in Unalaska Bay. On the shelf seaward of Amaknak Island (Stations HEL-1 and DUT-OB), the sedimentology indicates an active, "dynamic" environment. Here the grain-size mean falls in the sand range (2.2-2.8 ϕ); winnowing of the finer grained material has resulted in a well-sorted and coarse grained sediment cover.

The sediment character within the Hog-Amaknak Island channel is more complex. The shallowest portion is apparently subject to considerable bottom current action and is sedimentologically akin to the northern (seaward) shelf region. Stations 2A, 2B and 3J had rocky substrates which could not be easily sampled using the van Veen grab. It was in this region - in the vicinity of Station HEL-2 - that Colonell and Reeburgh (1978) obtained direct, near-bottom current measurements over these periods in September-October of 1977. The mean N-S Vector component range was found to be -1.18 - 2.83 cm/sec at approximately 1.5 m above the channel floor. Here negative velocities indicate currents from the south. These authors have also shown that wind and current directions closely correlate - i.e. that these currents are wind-dominated - and that the prevailing winds are northerly. Station 3I - close to the shore of Amaknak Island - also shows similar evidence of a dynamic environment: some 90% well-sorted, sand-sized material.

The group of stations southward of this saddle between the two islands - i.e. physiographically at the head of the Unalaska Bay indentation - have a markedly different sediment character. Here finer grained, poorly sorted sediment predominates and the organic carbon content is generally higher. Processing waste is accumulating at the shore-side outfall sites and - as noted in Section 8 - macroalgal debris appears to be accumulating in the vicinity of Stations 3AG, 3H, 3BF and 3D.

SECTION 6

BENTHIC BIOLOGICAL STUDIES

INTRODUCTION

The activities connected with seafood processing present potential dangers to the marine environment (see Olson and Burgess, 1967, for general discussion of marine pollution problems). Adverse effects to an environment cannot be assessed, or even predicted, unless background data are recorded prior to and during industrial operations.

Insufficient long-term information about an environment, and the basic biology and recruitment of species in that environment, can lead to erroneous interpretations of changes in types and density of species that might occur if the area becomes altered (see Nelson-Smith, 1973; Pearson, 1971, 1972; Rosenberg 1973; Pearson and Rosenberg, 1976; Rhoads *et al.*, 1978 for general discussions on benthic biological investigations in disturbed marine areas, also see Sect. 1 of the present report for examples of useful environmental data). Populations of marine species fluctuate over a time span of a few to 30 years (Lewis, 1970). Such fluctuations are typically unexplainable because of the absence of long-term data on physical and chemical environmental parameters in association with biological information on the species involved (Lewis, 1970). Additionally, the presence or absence of benthic species can be, in part, determined by the nature of the substrate. Specifically, the close relationships of benthic faunal assemblages to particular sediment characteristics have been shown for some areas (Jones, 1950; Sanders, 1958). Furthermore, the ability of larval forms of benthic species to select or reject a substratum on the basis of its physical and chemical properties has been determined experimentally (Wilson, 1953). Thus, changes in the substrate character may be reflected by changes in resident fauna. However, such changes can only be properly interpreted if the biota and associated substrata are investigated over a reasonable time base prior to and after disturbance of the particular area (see Rosenberg, 1973 and Pearson, 1972, 1975, for examples of such an approach for monitoring areas affected by industrial activity).

Benthic organisms (primarily the infauna but also sessile and slow-moving epifauna) are particularly useful as indicator species for a disturbed area because they tend to remain in place, typically react to long-range environmental changes, and by their presence, generally reflect the nature of the substratum. Consequently, the organisms of the infaunal benthos have frequently been chosen to monitor long-term pollution effects, and are believed to reflect the biological health of a marine area (see Pearson, 1971, 1972, 1975; and Rosenberg, 1973 for discussion on long-term usage of benthic organisms for monitoring pollution).

Experience in marine benthic areas influenced by industrial activity in England (Smith, 1968), Scotland (Pearson, 1972, 1975), Sweden (Rosenberg, 1976), and California (Straughan, 1971) suggests that at the completion of an initial exploratory study, selected stations should be examined regularly on a long-term basis to determine any changes in species content, diversity, abundance and biomass. Such long-term data acquisition should make it possible to differentiate between normal ecosystem variation and pollutant-induced biological alteration.

The benthic macrofauna of the southeastern Bering Sea shelf is relatively well known taxonomically, and some data on distribution, abundance, and feeding mechanisms are available as well (Feder *et al.*, 1976; Feder and Mueller, in press). The relationship of specific infaunal feeding types to certain substrate conditions also has limited documentation (Feder, unpub. OCSEAP data). However, detailed information on the temporal and spatial variability of the benthic fauna is sparse. Most of the benthic species in the vicinity of Dutch Harbor are the same as those reported by Feder *et al.* (1976) for the inshore shelf areas of the southeastern Bering Sea; thus, some comparisons are possible. Some of these species may be affected by processing activities. Thus, a further understanding of these species and their interactions with each other and various aspects of the abiotic features of their environment is essential to the development of environmental predictive capabilities for the Dutch Harbor area. The benthic biological survey reported here emphasized a quantitative inventory of species as part of a preliminary examination of the biological components of the bottom likely to be impacted by processing operations.

The investigation described in this report was designed (1) to provide preliminary biological information for the nearshore invertebrate benthos in Dutch Harbor and vicinity in the summer, and in association with hydrographic, water chemistry, and sedimentological investigations, (2) to establish a base suitable for development of a monitoring program in the area. The study examined the distribution and relative density of both infaunal and slow-moving epifaunal species.

RESULTS

General

Thirty-two stations were occupied with a van Veen grab. The material was returned to the University of Alaska where seventeen of the stations were processed and used in the numerical analyses reported below. Qualitative data from all other stations were used for interpretation of conditions in the study area. Twenty of the stations were monitored with an underwater television camera. All data are compiled in Appendices A-D.

Analysis of Stations from Field and Television Observations (see Figs. 2, 4; Appendices A-D for detailed data)

1. Dutch Harbor-Iliuliuk Bay: Stations DUT-00, DUT-0A, DUT-02, DUT-01A.
   The sediment at these stations was fine, gray to black in color with a strong sulfide odor noted. Few species were present; the polychaete *Nephtys cornuta* was dominant at all stations. Station DUT-0A had four species, DUT-02 had two species, DUT-00 had two species (only one infaunal component), and DUT-01A had four species present. DUT-0A was close to a sill (see Fig. 2); the sediment was lighter in color and the sulfide odor was less noticeable than at the other three stations.

2. Iliuliuk Harbor: Station 02A
   The sediment was fine, light gray in color with a moderate sulfide odor. Three species of polychaetes were present in low numbers.

3. Outer Dutch Harbor: Station DUT-0B
   Located seaward of a sill. Sediment was clean sand; no organic

odor detectable. Apparent burrowing activity of infauna visible as mounds on bottom. Many species present including polychaetes, clams, snails, amphipods, and sea urchins.

4. Stations Adjacent to Processing Plant Outfalls: 3E, 3DE, 3F, 3G, 3H, 3D, 3BF, 3AG, HEL-3A

The sample taken at Station 3E (located directly over the Universal Seafood outfall) was composed exclusively of processing wastes (primarily crustacean carapace fragments) in various stages of decomposi- invertebrates were present. At Station 3DE, located near the Universal Seafood outfall, the bottom was also composed of decaying processing wastes; a strong sulfide odor was detectable. No living organisms were present. The surface of the grab material at both of these stations was covered with several centimeters of fresh processing wastes layered over the major mass of old, blackened shellfish processing wastes.

The sediment at Station 3F, off the Vita Outfall, was sandy and clean with an organic odor; no sulfide odor detected. Polychaetous annelids were common; a few protobranch clams were present. The effluent was apparently discharging onshore through a break in the pipe some 100-150 meters from the station.

Station 3G, off the Pan Alaska-Whitney Fidalgo outfall, was composed of sandy, black sediment with a relatively strong sulfide odor. Small polychaetes and a few species of clams were common. Shrimp, probably *Pandalus hypsinotus* (coonstripe) were observed in the water column.

Station 3H - the bottom was primarily a black, sandy silt with a strong sulfide odor. Decaying macroalgae were present in four of the grabs; the fifth grab was sandy with no sulfide odor detectable.

Station 3D, approximately 300 m from the Universal outfall the tan sediment had organic odor; no sulfide detectable in three of the replicates. Two additional grabs had a minor sulfide odor, but fauna present were similar to that found in the first three grabs. Blackened plant material in latter two grabs. A snow crab (*Chionoecetes* sp.) was collected in one of the grabs that had a sulfide odor. All grabs were filled with worm tubes; polychaetes were common; also present were a few *Macoma* spp., several *Nuculana fossa* (a protobranch clam), and several small snails.

Stations 3AG, 3BF, HEL-3A - Located in the trough between Hog and Amaknak Islands approximately 250-350 m from the Universal Seafood outfall. Sediment oxic with mild to strong organic odor; no sulfide detectable. A variety of infaunal species present. Plant debris found at 3AG and 3BF. Large numbers of shrimp (probably *Pandalus hypsinotus*) present at 3AG.

5. Stations Adjacent to or on the Shallow Substrate Between Hog and Amaknak Island: 2A, 2B, HEL 2, 3I

The bottom consisted of pebbles, gravel, and rock with occasional presence of sand; epifaunal organisms were common on gravel and rocks. Pandalid shrimps, *Pandalus hypsinotus* were common at Station 3I. Greatly increased number of species, both infaunal and epifaunal, occurred at Station 3I.

6. North of Hog and Amaknak Islands: Station 1A, HEL 1, HEL 6

The sediment at all of the stations was clean, generally with a mild organic odor (no sulfide odor). A diverse and occasionally rich fauna was collected at the three stations, and consisted of polychaetes, clams, some snails, some brittle stars, and a few miscellaneous species. No processing wastes were present.

7. Transect Across Unalaska Bay Extending from Area South of Hog Island to Vicinity of Nateekin Bay: Stations 7A, HEL 7, 7B

The sediments were silty or sandy silt with variable amounts of organic material present; terrestrial plant debris was abundant at Station 7B. Polychaetes and clams were common at all stations on the transect.

8. Captains Bay: Stations HEL 4 and 4A

Silty sediment with mild organic odor (no sulfide). Polychaetes common; a few clams noted. This station group is separated by a sill from Iliuliuk Bay and Unalaska Bay. No processing wastes were present.

Numerical Analysis

A cluster analysis was run on data collected at the following stations (Figs. 2, 4; see Appendix Tables A-D for species composition of station groups):

DUT 00
DUT 0A
DUT 0B
3H
3C
DUT 01A
DUT 02
3BF
3B
3F
HEL 3
HEL 3A
HEL 7
3G
3I

Stations HEL 3E and HEL 3DE were not included in the analysis, because animals were not present at these stations. Station DUT 02A was also excluded because only one grab was collected (Appendix C), and the data could not be considered to be quantitative.

A normal cluster analysis using natural logarithm transformed data delineated seven (7) station groups at the 43% similarity level (Fig. 56; Table 17). Four of the "groups" formed, Station Groups 2, 5, 6, and 7, were composed of single stations. An inverse cluster analysis delineated 41 species-groups at the 60% similarity level (Table 18). A two-way coincidence table (Table 19) comparing the station groups formed by the normal cluster analysis and species groups formed by an inverse cluster analysis was utilized to determine the species which characterized each of the station groups. Station Group 1 was composed of stations inside the sill in Dutch Harbor (Fig. 4). Stations in Station Group 1 were characterized by a polychaetous annelid of the family Nephtyidae, *Nephtys cornuta*; these stations had a very low species richness and diversity (Table 20). Station Group 2 was composed of Station 3H located in Unalaska Bay on the west shore of Amaknak Island. *Nephtys cornuta* was also the dominant organism in this station and *Tharyx* sp., *Prionospio malmgreni*, *Axinopsida serricata*, were also common at this station. The diversity and species richness in Station 3H was slightly higher than that of stations in Station Group 1. Station Group 3 was composed of 3 offshore stations (3BF, 3C and HEL 7). These stations were characterized by Species Groups 14 through 19, and *Nephtys cornuta* (Species Group 21). The diversity, species richness and abundance of the fauna of stations in this group (Group 3) was higher than that of Station Groups 1 and 2

*Note - text continued on page 108

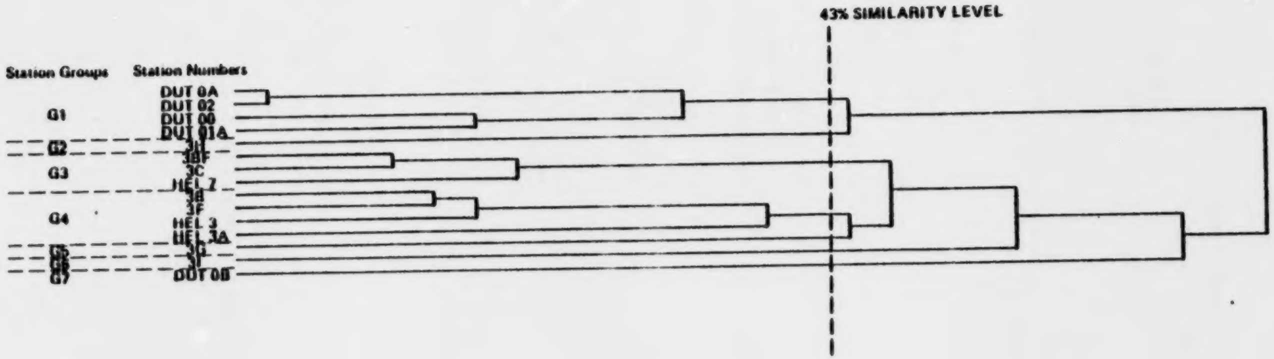


Figure 56. Dendrogram produced by cluster analysis using *ln* transformed numbers of individuals per m^2.

TABLE 17. STATION GROUPS FORMED BY CLUSTER ANALYSIS OF *ln* TRANSFORMED ABUNDANCE DATA

Station Group	Station Components	Notes
1	DUT 0A DUT 02 DUT 00 DUT 01A	Very low diversity and species richness. High dominance. Characterized by *Nephtys cornuta*
2	3H	Slight increase in diversity and species richness. Characterized by *Nephtys cornuta, Tharyx* sp., *Prionospio malmgreni* and *Axinopsida serricata*.
3	3BF 3C HEL 7	Increased diversity and species richness over the above Station Groups. Characterized by Species Groups[1] 14-19, 21.
4	3B 3F HEL 3 HEL 3A	Continued increase in diversity and species richness. Characterized by Species Groups 19-26.
5	3G	Reduced diversity and species richness. Characterized by Species Groups 19, 25, 26.
6	3I	Highest diversity and species richness. Characterized by Species Groups 15, 19-22, 28-34.
7	DUT 0B	Second highest diversity and species richness of all of the stations occupied. Characterized by Species Groups 1, 2, 3, 4, 5, 8, 9, 10, 19.

[1] Based on *ln* transformed data. See Table 19.

TABLE 18. SPECIES GROUPS FORMED BY AN INVERSE CLUSTER ANALYSIS OF *ln* TRANSFORMED ABUNDANCE DATA (#/m^2)

Species Group 1

- *Monoculodes* sp.
- *Echinarachnius parma*
- *Hesperonoe complanata*
- *Thracia beringi*
- *Retusa* sp.
- *Sigalion* sp.
- *Tellina lutea*
- *Lyonsia* sp.
- *Thracia* sp.
- *Diplodonta aleutica*

Species Group 2

- *Crenella dessicata*
- *Allocentrotus fragilis*
- *Psephidia lordi*
- *Ampelisca macrocephala*
- *Sthenelais* sp.
- *Lumbrineris bicirrata*
- *Mysella* sp.
- *Macoma moesta moesta*
- *Orchomene* sp.
- *Oenopota* sp.
- *Spisula polynyma*
- *Hippomedon* sp.
- *Paraphoxus* sp.
- *Magelona longicornis*
- *Cingula* sp.
- *Eudorellopsis deformis*

Species Group 3

- *Nephtys ferruginea*
- *Spisula* sp.

Species Group 4

- *Solariella obscura*

Species Group 5

- *Spiophanes bombyx*

Species Group 6

- *Spiophanes cirrata*
- *Praxillella praetermissa*

(continued)

TABLE 18 (continued)

Species Group 8

Tindaria sp.

Species Group 9

Harmothoe imbricata
Glycinde armigera
Solariella sp.

Species Group 10

Scoloplos fuliginosa
Prionospio sp.

Species Group 11

Golfingia margaritacea
Clinocardium ciliatum

Species Group 12

Brada inhabilis
Terebellides stroemii
Goniada maculata
Haploscoloplos sp.

Species Group 13

Onuphis iridescens
Melinna cristata

Species Group 14

Prionospio cirrifera
Chaetozone setosa
Eteone longa
Pholoe minuta

Species Group 15

Polynoe gracilis

Species Group 16

Aricidea jeffreysii

Species Group 17

Gyptis brevipalpa
Nephtys punctata

Species Group 18

Macoma brota

(continued)

TABLE 18 (continued)

Species Group 19

Scalibregma inflatum
Heteromastus filiformis
Lumbrineris luti
Prionospio malmgreni
Axinopsida serricata
Glycinde picta
Haploscoloplos elongatus

Species Group 20

Ammotrypane aulogaster

Species Group 21

Nephtys cornuta

Species Group 22

Glycera capitata
Lysippe labiata

Species Group 23

Spio filicornis
Ampharete arctica
Notomastus laeriatus
Capitella capitata
Nucula tenuis
Notomastus sp.
Axiothella catenata
Magelona pacifica
Chone cincta
Nuculana fossa
Macoma calcarea

Species Group 24

Spiophanes kroyeri

Species Group 25

Thyasira flexuosa

Species Group 26

Tharyx sp.

(continued)

TABLE 18 (continued)

Species Group 27

Acmaea sp.
Pinnixa sp.
Modiolus modiolus

Species Group 28

Pagurus sp.

Species Group 29

Paleanotus bellis
Exogone gemmifera
Oregonia gracilis
Phascolion strombi
Eunoe depressa
Trophonopsis sp.
Siphonaria sp.
*Collisella*sp.
Moelleria quadrai
Serpula sp.
Pododesmus macrochisma
Nereis sp.
Polydora ciliata
Pionosyllis gigantea
Exogone molesta
Harmothoe extenuata

Species Group 30

Idanthyrsus armatus
Balanus crenatus

Species Group 31

Anaitides sp.
Laonome kroyeri
Eunoe oerstedi
Eteone sp.
Polydora limicola
Owenia fusiformis
Ampharete sp.
Modiolus sp.
Chitinopoma groenlandica
Peisidice aspera
Pectinaria granulata
Hiatella sp.
Cryptobranchia concentrica
Spirorbis semidentatus

(continued)

TABLE 18 (continued)

Species Group 32

Mya sp.
Balanus sp.

Species Group 33

Myriochele heeri

Species Group 34

Clinocardium sp.

Species Group 35

Solariella sp.

Species Group 36

Heteromastus giganteus
Serripes groenlandicus
Syllis sp.
Spiophanes sp.

Species Group 37

Laonice sp.
Macoma carlottensis

Species Group 38

Cossura longocirrata
Yoldia thraciaeformis

Species Group 39

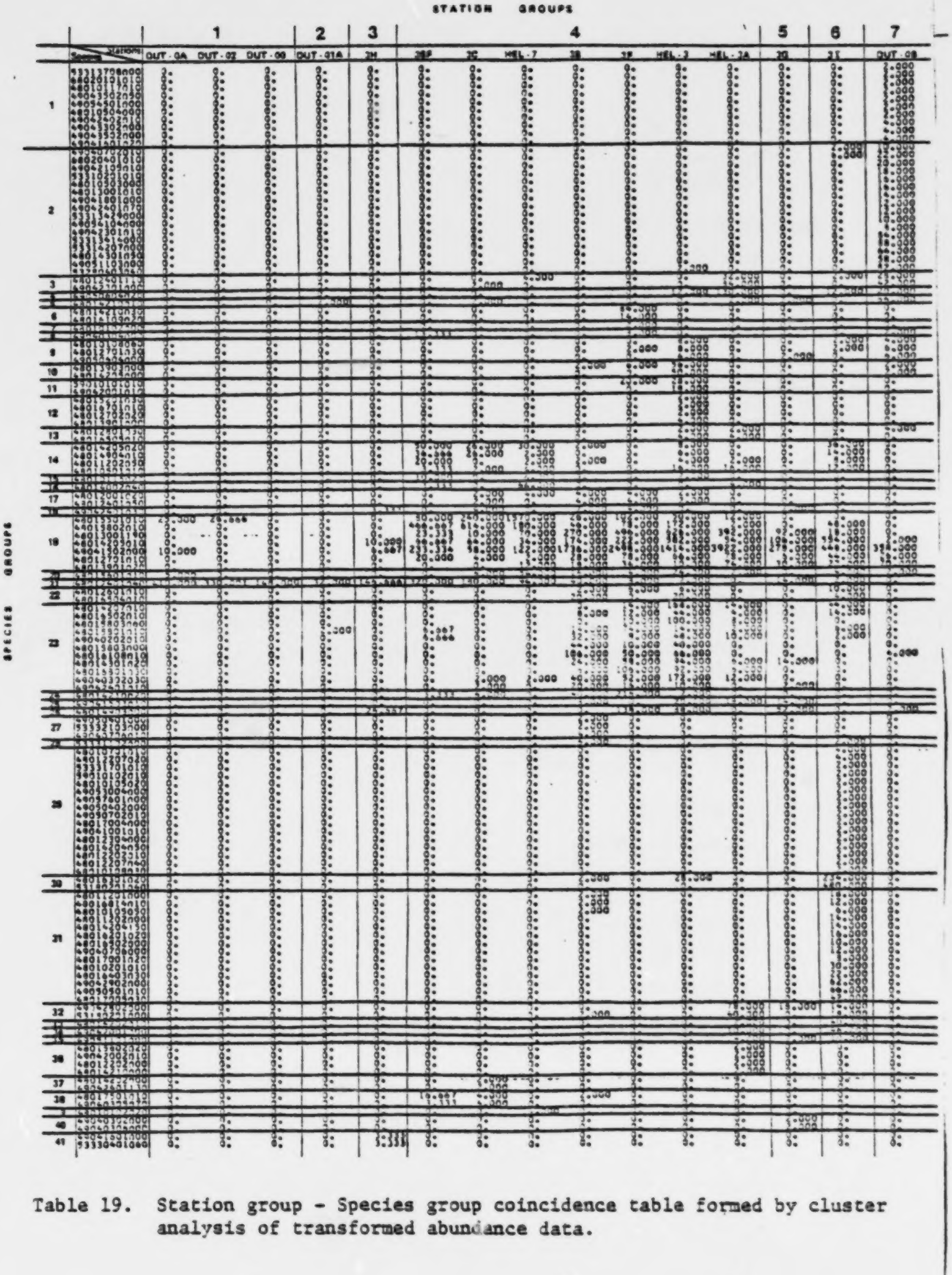
Antinoella sarsi

Species Group 40

Nuculana sp.
Yoldiella sp.

Species Group 41

Diplodonta sp.
Pandalus hypsinotus



STATION GROUPS

	1			2	3	4							5	6	7
Species \ Stations	OUT-0A	OUT-02	OUT-00	OUT-01A	2H	2BF	2C	HEL-7	2B	2F	HEL-3	HEL-2A	2G	2I	OUT-08

SPECIES GROUPS

Table 19. Station group - Species group coincidence table formed by cluster analysis of transformed abundance data.

TABLE 20. DIVERSITY (SIMPSON, SHANNON, BRILLOUIN) AND SPECIES RICHNESS OF STATION GROUPS FORMED BY A CLUSTER ANALYSIS OF *ln* TRANSFORMED DATA

Station Group 1	No. Ind/m^2	No. Species	Simpson Diversity	Brillouin Diversity	Shannon Diversity	Brillouin Evenness	Species Richness
DUT 00	150	2	0.97	0.06	0.07	0.09	0.19
DUT 0A	450	4	0.83	0.39	0.41	0.25	0.65
DUT 01A	38	4	0.37	1.01	1.17	0.71	1.09
DUT 02	357	2	0.86	0.25	0.27	0.37	0.17
$\bar{x}$	249	4	0.76	0.43	0.48	0.36	0.53
Station Group 2							
3H	213	8	0.49	1.07	1.14	0.53	1.30
Station Group 3							
3BF	1630	26	0.16	2.14	2.18	0.67	3.38
3C	1616	38	0.19	2.17	2.21	0.60	5.00
HEL 7	2338	32	0.21	2.06	2.10	0.60	3.99
$\bar{x}$	1861	32	0.19	2.12	2.16	0.62	4.12
Station Group 4							
3B	2902	50	0.37	1.82	1.85	0.47	6.15
3F	4556	46	0.32	1.95	1.98	0.51	5.34
HEL 3	4582	69	0.13	2.75	2.78	0.65	8.06
HEL 3A	5242	50	0.57	1.24	1.26	0.31	5.72
$\bar{x}$	4321	54	0.35	1.94	1.97	0.49	6.32
Station Group 5							
3G	702	26	0.21	2.04	2.11	0.64	3.82
Station Group 6							
3I	2946	85	0.10	2.97	3.03	0.68	10.51
Station Group 7							
DUT 0B	2184	59	0.13	2.67	2.72	0.67	7.54

(Tables 17, 20), Station Group 4 was composed of 4 stations (3B, HEL 3A, HEL 3, 3C) south of Hog Island and Station 3F adjacent to Amaknak Island. These stations were characterized by Species Groups 17, 19, 20, 21, 22, 23, 24, 25 and 26 *Axinopsida serricata* was the dominant organism in these five stations, and it ranged in abundance from 1414 individuals/m^2 in Station HEL 3 to 3922 ind/m^2 in Station HEL 3A. The abundance and species richness of the fauna in the stations of Station Group 4 was higher than that in Station Groups 1-3. However, the diversity in some of the stations in Group 4 was lower than that of stations in Group 3 and 5, because the high abundance of *Axinopsida serricata* in several Group 4 stations reduced the evenness component of the diversity index, thus reducing the diversity.

Station Group 5 was composed of one station, 3G, close to Amaknak Island, and was composed of three species groups (19, 25, 26, 32). The dominant species at this station were the polychaetes *Lumbrineris luti*, *Prionospio malmgreni* and *Tharyx* sp., and the clam *Axinopsida serricata*. The abundance and species richness of Station 3G was lower than that of Station Groups 3 and 4 while the diversity, as noted above, was higher than that of Station Group 4; the abundance, diversity and species richness was higher than that of Station Groups 1 and 2.

Station Group 6 was composed of one station, 3I, close to Amaknak Island adjacent to a shallow sill. Station 3I was composed of Species Groups 15, 19, 20, 21, 22, 28, 29, 30, 31, 32, 33, 34. The most common organisms at this station were *Prionospio malmgreni*, *Spio filicornis*, Cirratulidae, *Heteromastus filiformis*, *Myriochele heeri*, *Idanthyrsus armatus*, *Spirorbis semidentatus*, *Axinopsida serricata*, *Macoma* sp., *Hiatella* sp., *Cryptobranchia concentrica*, *Balanus crenatus*, Amphipoda. The diversity and species richness was the highest of all station groups.

Station Group 7 was composed of one station, DUT 0B, located just outside of Iliuliuk Bay and separated from the Bay by a shallow sill. Station DUT 0B comprised Species Groups 1, 2, 3, 4, 5, 8, 9, 10, 19. The most common organisms were Foraminifera, *Haploscoloplos elongatus*, *Spiophanes bombyx*, *Magelona longicornis*, Cirratulidae, *Axinopsida serricata*, *Spisula* sp., *Cingula* sp., *Eudorellopsis deformis*, Amphipoda, Strongylocentrotidae. This station had the second highest diversity and species richness of all the stations occupied.

Station groups formed by a cluster analysis of untransformed abundance data are presented in Figure 57 and Table 21.

DISCUSSION

Sampling Efficiency of the van Veen Grab

The van Veen grab functioned effectively in the fine sediments covering most of the sampling area, and typically delivered 15-19 liters of sediment. Penetration was reduced in sites with considerable concentrations of sand or gravel. The surface of all samples, examined through the top door of the grab, was relatively undisturbed as evidenced by the smooth detrital cover (see Feder *et al.*, 1973, for further discussion).

Analysis Based on Field and Television Observation (see Appendices A-D; Table 22 for detailed data; Fig. 2)

The number of infaunal species present in the Dutch Harbor-Iliuliuk Bay basin is very much reduced with one polychaete worm, *Nephtys cornuta*, dominant at all of the stations (DUT 00, 0A, 02 01A, 02A). The paucity of the fauna at stations in this region appears to reflect the stressful aspects of the reducing conditions present throughout the basin. Sulfide concentrations, as determined qualitatively by sight and odor of sediment samples on shipboard, were greatest at Station DUT 01A, a site located within the old shellfish disposal area of several years ago. The few infaunal organisms present here were primarily deposit-feeding polychaetes. Sulfide deposition was also extensive at DUT 00 located in the approximate center of Iliuliuk Bay, and only one infaunal species, the deposit-feeding polychaete *N. cornuta*, was found here. Sulfide concentration was also high at DUT 02, inner Iliuliuk Bay, with concomitant reduced number of infaunal species present - two deposit-feeding polychaetes. DUT 02A, a station adjacent to most of the processing plants in Iliuliuk Harbor (Fig. 1), also contained a reduced number of species (three species) of polychaetes: two deposit feeders, one suspension feeder. Sulfide concentration appeared to be less here than that at DUT 01A and DUT 00. Station DUT 0A, located in outer Iliuliuk Bay, adjacent to a shallow sill separating the bay from the Bering Sea, is influenced by its proximity to

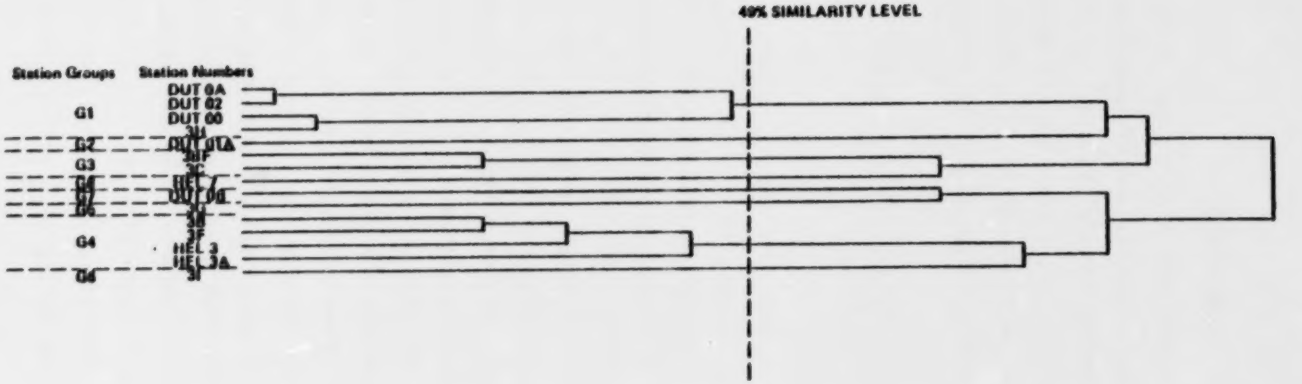

49% SIMILARITY LEVEL
Station Groups
Station Numbers
DUT 0A
DUT 02
DUT 00
3H
DUT 01A
3C
HEL 7
DUT 06
3F
HEL 3
HEL 3A
G1
G2
G3
G4

Figure 57. Dendrogram produced by cluster analysis using number of individuals per m^2.

TABLE 21. STATION GROUPS FORMED BY CLUSTER ANALYSIS OF *ln* TRANSFORMED AND UNTRANSFORMED ABUNDANCE DATA

	Transformed Data	Untransformed Data
Station Group 1	DUT 0A	DUT 0A
	DUT 02	DUT 02
	DUT 00	DUT 00
	DUT 01A	3H
Station Group 2	3H	DUT 01A
Station Group 3	3BF	3BF
	3C	3C
	HEL 7	——
Station Group 8	——	HEL 7
Station Group 4	3B	3B
	3F	3F
	HEL 3	HEL 3
	HEL 3A	HEL 3A
Station Group 5	3G	3G
Station Group 6	3I	3I
Station Group 7	DUT 0B	DUT 0B

TABLE 22. FEEDING[1] AND MOTILITY[2] CLASSES OF COMMON BENTHIC INVERTEBRATES FROM DUTCH HARBOR, ALASKA, BENTHIC SAMPLES OF JUNE 1978

Phylum	Identified Taxon	Family	Common Name	Feeding Class	Motility Class
Protozoa	Foraminifera	-	-	P	M
Cnidaria	Anthozoa	-	anemone	SF	S
Rhynchocoela	Rhynchocoela	-	ribbon worm	P	M
Annelida	Polynoidae	-	segmented worm	S	M
Annelida	*Harmothoe imbricata*	Polynoidae	segmented worm	S	M
Annelida	*Polynoe gracilis*	Polynoidae	segmented worm	S	M
Annelida	*Pholoe minuta*	Sigalionidae	segmented worm	S	M
Annelida	*Eteone longa*	Phyllodocidae	segmented worm	P	M
Annelida	*Gyptis brevipalpa*	Hesionidae	segmented worm	P	M
Annelida	*Nephtys cornuta*	Nephtyidae	segmented worm	DF/P	M
Annelida	*Nephtys punctata*	Nephtyidae	segmented worm	DF/P	M
Annelida	*Nephtys ferruginea*	Nephtyidae	segmented worm	DF/P	M
Annelida	*Glycera capitata*	Gylceridae	segmented worm	DF/P	M
Annelida	*Glycinde picta*	Goniadidae	segmented worm	DF/P	M
Annelida	*Glycinde armigera*	Goniadidae	segmented worm	DF/P	M
Annelida	*Onuphis iridescens*	Onuphidae	segmented worm	DF	S/DM
Annelida	*Lumbrineris luti*	Lumbrineridae	segmented worm	DF/P	M
Annelida	*Haploscoloplos elongatus*	Orbiniidae	segmented worm	DF/	M
Annelida	*Scoloplos fuliginosa*	Orbiniidae	segmented worm	DF	M
Annelida	*Aricidea jeffreysii*	Paraonidae	segmented worm	DF	M
Annelida	*Polydora* sp.	Spionidae	segmented worm	DF	DM
Annelida	*Prionospio malmgreni*	Spionidae	segmented worm	DF	DM
Annelida	*Prionospio cirrifera*	Spionidae	segmented worm	DF	DM
Annelida	*Spio filicornis*	Spionidae	segmented worm	DF	DM
Annelida	*Spiophanes bombyx*	Spionidae	segmented worm	DF	DM
Annelida	*Spiophanes kroyeri*	Spionidae	segmented worm	DF	DM
Annelida	*Magelona pacifica*	Magelonidae	segmented worm	DF	DM
Annelida	Cirritulidae	Cirratulidae	segmented worm	DF	S/DM
Annelida	*Tharyx* sp.	Cirratulidae	segmented worm	DF	S/DM
Annelida	*Chaetozone setosa*	Cirratulidae	segmented worm	DF	DM
Annelida	*Scalibregma inflatum*	Scalibregmidae	segmented worm	DF	DM
Annelida	*Ammotrypane aulogaster*	Opheliidae	segmented worm	DF	DM
Annelida	Capitellidae	Capitellidae	segmented worm	DF	M
Annelida	*Capitella capitata*	Capitellidae	segmented worm	DF	M
Annelida	*Heteromastus filiformis*	Capitellidae	segmented worm	DF	M
Annelida	*Notomastus* sp.	Capitellidae	segmented worm	DF	M
Annelida	*Notomastus laeriatus*	Capitellidae	segmented worm	DF	M
Annelida	Maldanidae	Maldanidae	segmented worm	DF	S
Annelida	*Axiothella catenata*	Maldanidae	segmented worm	DF	S
Annelida	*Myriochele heeri*	Owenidae	segmented worm	SF/DF	S
Annelida	*Idanthyrsus armatus*	Sabellariidae	segmented worm	SF	S
Annelida	Ampharetidae	Ampharetidae	segmented worm	DF	S
Annelida	*Ampharete arctica*	Ampharetidae	segmented worm	DF	S

TABLE 22 (continued)

Phylum	Identified Taxon	Family	Common Name	Feeding Class	Motility Class
Annelida	*Lysippe labiata*	Ampharetidae	segmented worm	DF	S
Annelida	*Chone cincta*	Sabellidae	segmented worm	SF	S
Annelida	*Spirorbis semidentatus*	Serpulidae	segmented worm	SF	S
Annelida	*Cossura longocirrata*	Cossuridae	segmented worm	DF	M
Mollusca	*Nucula tenuis*	Nuculidae	clam	DF	M
Mollusca	Nuculanidae	Nuculanidae	clam	DF	M
Mollusca	*Nuculana fossa*	Nuculanidae	clam	DF	M
Mollusca	*Tindaria* sp.	Nuculanidae	clam	DF	M
Mollusca	*Yoldia* sp.	Nuculanidae	clam	DF	M
Mollusca	*Yoldia thraciaeformis*	Nuculanidae	clam	DF	M
Mollusca	*Axinopsida serricata*	Thyasiridae	clam	SF/DF	S
Mollusca	*Thyasira flexousa*	Thyasiridae	clam	SF/DF	S
Mollusca	*Clinocardium ciliatum*	Cardiidae	cockle	SF	M
Mollusca	*Spisula polynyma*	Mactridae	clam	SF	M
Mollusca	*Macoma* sp.	Tellinidae	clam	DF	S
Mollusca	*Macoma calcarea*	Tellinidae	clam	DF	S
Mollusca	*Macoma brota*	Tellinidae	clam	DF	S
Mollusca	*Hiatella arctica*	Hiatellidae	clam	SF	S
Mollusca	*Mya* sp.	Myidae	clam	SF	S
Mollusca	*Cryptobranchia concentrica*	Lepetidae	limpet		
Mollusca	*Solariella* sp.	Trochidae	snail	S/P	M
Mollusca	*Solariella obscura*	Trochidae	snail	S/P	M
Mollusca	*Alvinia* sp.	Rissoidae	snail	S/P	M
Arthropoda	*Balanus* sp.	Balanidae	barnacle	SF	S
Arthropoda	*Balanus crenatus*	Balanidae	barnacle	SF	S
Arthropoda	Cumacea	-	-	DF	M
Arthropoda	Amphipoda	-	sand flea	DF/S	M
Arthropoda	*Pandalus hypsinotus*	Pandalidae	shrimp	S/P	M
Echinodermata	Ophiuridae	-	brittle star	DF	M
Chordata	Pholididae	-	fish-gunnel	DF	M

[1] P = predator; SF = suspension feeder; DF = deposit feeder; S = scavenger

[2] M = motile; DM = discretely motile; S = sessile

a region of extensive mixing. Only a moderate sulfide odor was detectable in sediments here. However, only four infaunal species were present. The number of individuals of each infaunal species at DUT 0A was high in comparison to densities at DUT 01A and 02A. In general, conditions in Iliuliuk Bay are not presently conducive to the establishment of the diverse assemblages of species found at DUT 0B, just outside of Iliuliuk Bay (see Discussion below).

Station DUT 0B is located approximately 2000 m from DUT 0A, and is separated from the latter station by a shallow sill (Fig. 2). The overlying waters in the vicinity of DUT 0B are well mixed. The sediment was clean sand, and no organic odor was detectable. The bottom, as viewed by television, reflected the activities of infaunal species, as opposed to the uniform sediment surface visible at stations in Iliuliuk Bay and Iliuliuk Harbor. A dramatic increase of species occurred at DUT 0B: 59 species here, in contrast to a mean of 4 species at stations in Iliuliuk Bay.

The bottom on and adjacent to the Universal Seafood outfall (Stations 3E and 3DE) was covered by blackened processing wastes. The very extensive amount of wastes present and the marked reducing conditions associated with them strongly suggests that these wastes are accumulating, and are not being removed to any extent by water movement. No infaunal organisms were able to tolerate the toxic conditions associated with the decaying processing wastes. Similar observations were reported for this region in 1976 and 1977 (Karna, 1978).

The bottom approximately 100 m north of the Vita Food Products outfall (Station 3F) was free of processing wastes, and sulfide was not detectable in the grab samples. A large number of species were present (46) with polychaetes and clams dominant. Effluent was apparently discharging through a break in the pipe onshore some 100-150 m from Station 3F. The relative health of the infauna of the area and lack of processing wastes in the grab samples indicate that little or no material is moving from the disposal sites described in Karna (1978) to adjacent areas.

The sediment, as observed in the grab samples, at Station 3G near the Pan Alaska-Whitney Fidalgo outfalls was black with a strong sulfide odor. Although processing wastes were not detectable (i.e., crustaceans skeletal parts), the marked reducing conditions present here suggest that dissolved or particulate organic material is carried into the area. The reduced number of infaunal species (26) here reflects the presence of sulfide in the sediment. Again, the lack of skeletal fragments from the nearby outfall indicates little movement of the larger fractions of processing material from the waste piles (see Karna, 1978 for photographs and diagrams) to adjacent areas. The fully oxygenated conditions of the overlying waters was emphasized by the presence of healthy shrimp and fish over the bottom at Station 3G (Appendix C).

The bottom at Station 3H, north of 3G, varied from a light-colored oxic to a black anaerobic sediment. No processing wastes were detectable, and the reducing conditions present here were presumably a response of the system to the accumulation of macrophytes (algae) in the area. The toxic conditions at this station are demonstrated by the presence of only eight infaunal species.

The polychaete *N. cornuta* was dominant here as it was at Stations DUT 00, 0A, 02, 01A, 02A in Iliuliuk Bay where sediment sulfide concentrations were also high. The accumulation of plant material on the bottom at this station once again suggests that water movement is sufficient for removal and transport of dense materials, such as processing wastes, from the shallow shelf of Amaknak Island.

The well-mixed shallow area at Station HEL-2, as well as adjacent nearshore stations (3I, 3J, 2A and 2B), showed increased numbers of species (e.g. 3I has 85 species). No processing wastes were evident at these stations.

The bottom between Hog and Amaknak Islands was enriched with organic material (Stations 3BF, 3AG), although no sulfide odor was detectable. No processing wastes were present, but terrestrial plant debris had accumulated at Stations 3AG and 3BF, indicating little water movement here. Twenty-six infaunal species were present at Station 3BF.

The bottom at Station HEL-3A, close to 3BF and 3AG, did not have accumulations of plant debris present, and no processing wastes were present. An organic odor was noticeable, but a sulfide odor was not detectable in the sediment. Fifty species were present at HEL 3A. Accumulation of plant and processing wastes might be expected at HEL-3A if the accumulated wastes in shallow water were dispersed by water movement (e.g. longshore currents, tidal action, wave activity). The relatively clean bottom at this station (as well as lack of processing wastes at 3BF and 3AG) indicates that wastes are not being moved to or deposited in the channel located less than one mile from the processing plant outfalls.

An examination of a transect extending from the Universal Seafood outfall site (Station 3E where no infaunal organisms were found) through a series of stations extending to the far side of Unalaska Bay demonstrates changes on the bottom at varying distances from a point source of pollution. Some of the stations on this transect were also sampled for hydrographic data (see Fig. 3; Sect. 5). A summarization of some data at the appropriate stations is tabulated below (see Table 20; Appendix C):

Station	No. species present	Brillouin diversity	Species richness	Approx. dist. from 3E (outfall) (m)	Comments
3E	0	-	-	0	At discharge point. H_2S present
3DE	0	-	-	100	Processing wastes. H_2S present
3BF	26	2.14	3.38	250-300	Large amount terrestrial plant debris. No H_2S. Strong organic odor.
3C	38	2.17	5.00	750-800	No debris. Clean. Mild organic odor.
3B	50	1.82	6.15	750-800	No debris. Clean. Mild organic odor.
HEL-3	69	2.75	8.06	1200-1400	No debris. Clean. Mild organic odor.
HEL-7	32	2.06	3.99	2500-2700	No debris. Clean. No odor.

The summary above and the previous discussion for all stations indicate that the negative effects of processing wastes do not extend far from the point source of discharge. On the other hand, dissolved and small particulate wastes dispersing from the point source may enrich the bottom and serve as an additional food source for infaunal deposit feeders in adjacent areas. No benthic infauna can be expected under and directly next to accumulations of processing wastes.

Numerical Analysis: General

Numerical analysis makes the evaluation of large data sets feasible, and its use has greatly reduced the subjective element in the analysis of benthic faunal distributions. However, numerical techniques have not completely eliminated subjectivity. Among the subjective decisions required during the development of the numerical analysis protocols used in this study were the selection of (1) a method of data standardization of transformation (if any were desired); (2) a similarity coefficient; and (3) a clustering strategy or method of ordination. A subjective judgement delimiting the groups formed by the analysis must also be made, either by examining a dendrogram (classification) or loadings of points on coordinate or component axes (ordination). The effectiveness of the analysis chosen for this study (classification) was evaluated by using two-way coincidence tables and examining the extent to which the groupings formed by cluster analysis reflected environmental (physical, chemical, biological) conditions.

Some form of data transformation or standardization has often been utilized in the analysis of benthic communities (Field and MacFarlane, 1968; Field and Robb, 1970; Ebeling *et al.*, 1970; Day *et al.*, 1971; Thorrington-Smith, 1971; Stephenson and Williams, 1971; Stephenson *et al.*, 1972; Raphael and Stephenson, 1972; Williams and Stephenson, 1973; Levings, 1975; Maurer *et al.*, 1978). Boesch (1973) used a double standardization to eliminate the effects of differences in abundance between individuals. He argued that two species which might have "similar habitat requirements, yet one is always much more abundant than the other", would be segregated by the analysis unless abundances are standardized. Some form of standardization or transformation should be utilized; however, differences in abundance may also imply that differences in the suitability of the habitat for the species in question may, in fact, exist. In the absence of a thorough knowledge of the habitat requirements of the species utilized for the analysis we feel that both unaltered and transformed or standardized data should be examined.

The Czekanowski coefficient was used in the present study to calculate similarity matrices for cluster analysis because it tends to emphasize the effect of dominant species on the classification. Raphael and Stephenson (1972) found that the Czekanowski coefficient, with its emphasis on dominant species, produced station groups that were more closely correlated with abiotic attributes.

A hierarchical agglomerative clustering strategy was used to create dendrograms from similarity matrices. We have found that the group average sorting strategy gives useful results, and we have used it almost exclusively here. Boesch (1973) and Stephenson *et al.* (1972) used both group average and "flexible" sorting strategies (Lance and Williams, 1966). Boesch (1973) found the flexible strategy yielded "the more instructive classification" while Stephenson *et al.* (1972), using a variety of criteria, found both strategies to have merit. We experimented with the use of the flexible sorting strategy with $\alpha = 0.85$ using data collected in the northeastern Gulf of Alaska (Feder and Matheke, in press), and found that the results were not appreciably different from those obtained using the group average strategy.

Numerical Analysis: Data From Grab Samples

The station groups formed by a cluster analysis of untransformed abundance data (Fig. 57) were similar to those formed by cluster analysis of natural logarithm transformed data (Fig. 56). The only differences between the results of these two analyses were (Table 21):

1. Station 3H switched from Group 2 (*ln* transformed data) to Group 1 when untransformed data were used.
2. Station DUT 01A switched from Group 1 (*ln* transformed data) to Group 2 when untransformed data were used.
3. Station HEL 7 was split from Group 3 (*ln* transformed data) to form a new "single station" group, Group 8 untransformed data.

When untransformed data are used, the effect that dominant species have on the analysis is emphasized (see Appendices A-D for data). Thus, when untransformed data was used, Station DUT 01A was excluded from Group 1 because of differences in the abundance of the dominant species, *Nephtys cornuta* in both Group 1 and Group 2 stations. The abundance of *Nephtys cornuta* was lower in Station DUT 01A than in the other stations in Group 1. Similarly Station 3H was included in Group 1 when untransformed data was used because the abundance of *Nephtys cornuta* in the station was similar to that of Stations DUT 0A, 02, 00, even though Station HEL 3H was less similar to Stations DUT 0A, 02, 00, in terms of its total species composition. Station HEL 7 differed from the other stations in Station Group 3 in the abundance of the polychaetous annelid *Scalibregma inflatum*. This polychaete was much more abundant in Station HEL 7 (1570 ind/m^2) than in Stations 3BF and 3C ($\bar{x}$ = 160.0 ind/m^2) and as a result Station HEL 7 was not included in Station Group 3 when untransformed data was used.

Stations 3DE and 3E were not included in the analysis because no fauna was collected in these stations. According to the coefficient, the Czekanowski coefficient, used for calculating similarities they would have no similarities with any station group. In reality these stations are more similar to Stations DUT 0A, 02, 00, 01A, and HEL 3H, all of which have a very low species richness (number of species) and low densities of individuals, than they are to other stations with a greater number of species.

Combined Analysis Based on Field and Television Observations and Numerical Analysis

A qualitative assessment of the conditions within the study area in conjunction with numerical analysis of grab data have clarified the relationship of benthic infauna to seafood processing waste discharge in the Dutch Harbor area. The numerical analysis delineated seven station groups, and 41 species groups associated with the station groups. An assessment of the relationships of station and species groups as delineated by numerical analysis strengthens the qualitative assessment of each station made by underwater television and direct observation of grab material on shipboard.

All analyses indicate that the Dutch Harbor-Iliuliuk Bay basin (Station Group 1 as formed by cluster analysis; Table 17; Appendix C) is a stressed area with few infaunal individuals and species present. The anoxic conditions that may normally occur within this basin in the fall would result in a reduced infauna there. Additional stresses to the system by way of increased organic loading (e.g. processing wastes) and oxygen demand would further reduce the number of infaunal species that could survive in the area.

The sea bottom at the point of discharge of processing wastes and areas immediately adjacent to that point are always anaerobic and reducing environments. No infaunal or epifaunal organisms can be expected to survive such conditions, and none were observed in this study. However, as indicated in the previous discussion, the effects of shellfish wastes were dissipated over a relatively short distance. The stations on the west side of Amaknak Island near the waste outfalls are considered in the Results and previous Discussion sections of this report (also see Appendix C). Variable conditions exist at these stations depending on their distance from outfalls, the presence or absence of plant material, their location in the channel between Hog and Amaknak Islands where water movement is reduced, and their proximity to the shallow sill between Hog and Amaknak Islands where well-mixed water is found. The interpretation of the effects of processing wastes are complicated by the presence of algal accumulations at Stations 3D, 3H, 3AG, 3BF, 7B on the far side of Unalaska Bay. Stress on the benthic system in the Dutch Harbor basins must be a common occurrence whenever plant (marine and terrestrial) material accumulates on the bottom. The additional input of processing wastes to such a stressed system in conjunction with reduced water movement (e.g. inside a sill) can be expected to alter the benthic infauna. Ultimately, pelagic organisms (e.g. shrimps) would be affected if hydrogen sulfide diffuses into overlying waters in the stressed areas, as noted at Station DE in the present study (see Sect. 5).

An examination of all station groups formed by cluster analysis and the qualitative assessment of species in these groups and at stations not processed, suggest that a reasonable data base now exists to monitor the

Dutch Harbor area. The infaunal species are now well known, and the use of numerical analysis will make it possible to assess change in bottom fauna as industrial activity progresses.

Underwater television used in conjunction with bottom sampling is also a good tool to examine the shallow bottom regions on a continuing basis. The TV monitor can identify stressed areas by identifying relative amounts of suspended processing wastes, accumulations of processing wastes on the bottom, and the color of the bottom - a black bottom indicating extreme reducing conditions.

SECTION 7

GENERAL DISCUSSION

A variety of coastal environments are present in the vicinity of Dutch Harbor. North (NE & NW) of Amaknak Island is a dynamic region facing the Bering Sea and blanketed with coarse grained, well-sorted sediment. The head of Unalaska Bay (which itself appears to be relatively quiet at depth) lies immediately south of a shallow sill structure between Hog and Amaknak Islands separating it from the active region northwards. Net water movement (at least in the summer) appears to be southwards through the channel and south of this sill the relatively carbon-rich surficial sediment is finer grained and poorly sorted. A number of stations in this latter region show accumulations of algal debris and it is here that the bulk of the shellfish processing waste is currently being dumped. Because of the apparently restricted bottom circulation here, this waste material is not well dispersed and a very localized patch of anoxic water was observed.

Processing waste was formerly discharged directly into Dutch Harbor proper which, with Iliuliuk Bay, comprises one of the two physically restricted coastal basins. The other - much deeper - basin is the adjacent Captains Bay. At the time of year sampled (June) the spring phytoplankton bloom was apparently complete in this region and the water within the basins was well stratified and isolated from the adjacent shelf waters. Nitrate was depleted at the surface and there were strong positive gradients for, in particular, ammonia, phosphate and silica to the bottom, due to regeneration at depth and in the surface sediments. Because of this active consumption and lack of advective influx of new water, dissolved oxygen concentrations at the base of the water column in Dutch Harbor were less than 5 ml/ℓ. However, this consumption rate (assuming isolation of the basin water at approximately the same time of year) is not conspicuously different from that observed a decade previously, at which time the additional organic loading due to processing waste was much higher. From data obtained the previous September (1977) it appears that oxygen depletion continues through the summer and that anoxic conditions occur in late summer-fall at depth, persisting until new shelf water flushes to be annual and is apparently a natural consequence of local productivity and terrestrial carbon input; ie., while anthropogenic carbon dumping must exacerbate the situation, it is unlikely to be, *per se*, the cause of summer basin anoxia. Chemical trends in Captains Bay proceed along similar paths but the greater volume of water there, and possibly unknown differences in natural carbon input, do not allow complete removal of oxygen within the water column. The sediments in both these basins are anoxic almost to the surface and, particularly in Dutch Harbor, there is a substantial additional flux of phosphate into the water.

The infaunal composition within the Dutch Harbor-Iliuliuk Bay basin reflects a biologically stressed system. The anoxic conditions that normally occur seasonally within this basin at depth contribute to the depauperate conditions present there. However, additional stresses to this system by way of plant debris and/or processing wastes would be expected to increase the oxygen demand by the benthos and result in a further reduction of infaunal species present. It is obvious that the future deposition of processing wastes in this basin would be ecologically unsound.

Processing wastes accumulating on the shallow shelf on the west side of Amaknak Island are responsible for severe anoxic and reducing conditions on the bottom at the site of and immediately adjacent to effluent piles. No benthic infaunal organisms are surviving under or close to the waste accumulations. However, the negative effects of these wastes dissipate over relatively short distances from the accumulated deposits, and healthy infaunal populations occur within a few hundred meters of these deposits.

It is apparent that processing wastes are accumulating adjacent to outfalls off Amaknak Island and that the existing water currents do not provide sufficient energy for adequate dispersal of the wastes (also see report of Stewart and Tangerone, 1977). Thus, although processing wastes are not presently impacting broad areas near outfalls, it is probable that accumulated wastes adjacent to Amaknak Island will eventually cover much of the nearshore bottom with potentially serious ecological and sanitary problems to be expected.

The television camera, used in conjunction with the grab, is a useful tool to delineate the extent of bottom areas contaminated by processing wastes. Stations, with a black bottom, indicating the presence of sulfide, was detectable by the camera and was verified by the van Veen Grab.

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APPENDIX A

SUMMARY OF ALL SPECIES DATA FOR STATIONS ANALYZED IN THE LABORATORY

DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

STATION-SAMPLE LISTING 03/25/79 PAGE 1

		TOT CNT	TOT WWGT	CNT/SQM	WWGT/SQM	GRABS				
CRUISE 261	STATION 0A	91.	0.557	455.	2.785	1	2			
CRUISE 261	STATION 0B	1100.	98.540	2200.	197.080	1	2	5	4	3
CRUISE 261	STATION 00	75.	0.286	150.	0.572	5	4	3	2	1
CRUISE 261	STATION 01A	19.	0.668	38.	1.336	2	5	4	3	1
CRUISE 261	STATION 02	108.	1.085	360.	3.617	5	4	3		
CRUISE 261	STATION 02A	7.	0.024	70.	0.240	1				
CRUISE 261	STATION 3	2307.	67.145	4614.	134.290	4	5	3	2	1
CRUISE 261	STATION 3A	2630.	64.877	5260.	129.754	2	1	3	4	5
CRUISE 261	STATION 3B	1459.	103.614	2918.	207.228	1	5	4	3	2
CRUISE 261	STATION 3BF	494.	19.886	1647.	66.293	3	2	1		
CRUISE 261	STATION 3C	820.	349.339	1640.	698.678	5	4	3	1	2
CRUISE 261	STATION 3E	0.	0.	0.	0.	1				
CRUISE 261	STATION 3F	2289.	99.041	4578.	198.082	2	5	1	4	3
CRUISE 261	STATION 3G	356.	40.599	712.	81.198	3	4	5	1	2
CRUISE 261	STATION 3H	66.	26.920	220.	89.733	5	2	1		
CRUISE 261	STATION 3I	1480.	2773.256	2960.	5546.512	3	1	4	2	5
CRUISE 261	STATION 7	1176.	167.697	2352.	335.394	2	5	3	4	1

TOTAL NUMBER OF STATIONS = 17.

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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                              03/25/79       PAGE    2

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS             CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION         CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION

TAXON CODE              TAXON NAME                                  CRIT1  CRIT2  CRIT3  CRIT4  CRIT5     STA OCC

310431000000                FORAMINIFERA                                     X             X                 2
330100000000            HYDROZOA                                                                             1
330300000000            ANTHOZOA                                                    X             X          1
3303000000F0            ANTHOZOA FRAGS                                                                       1
340000000000       CTENOPHORA                                                                                1
400000000000       RHYNCHOCOELA                                                                              6
4000000000F0       RHYNCHOCOELA FRAGS.                                              X             X          6
440000000000       NEMATODA                                                                                  1
4800000000F0       ANNELIDA FRAGS                                                                            4
480100000000            POLYCHAETA                                                                           2
4801000000F0            POLYCHAETA FRAG.                             X                                      12
480101000000                 POLYNOIDAE                                                                      8
480101020000                      NEMIDIA SP.                                                                1
480101020200                      ANTINOELLA SARSI                                                           1
480101050200                      EUNOE DEPRESSA                                                             1
480101050500                      EUNOE OERSTEDI                                                             2
480101080300                      HARMOTHOE EXTENUATA                                                        1
480101080600                      HARMOTHOE IMBRICATA                                                        3
480101150200                      POLYNOE GRACILIS                                                           3
480101170100                      HESPERONE COMPLANATA                                                       1
480102010100                      PEISIDICE ASPERA                                                           1
480105000000                 SIGALIONIDAE                                                                    2
480105010100                      PHLOE MINUTA                                       X                       7
480105030000                      STHENELAIS SP.                                                             1
480105040000                      SIGALION SP.                                                               1
480107010100                      PALEANOTUS BELLIS                                                          1
480112010000                      ANAITIDES SP.                                                              2
480112020000                      ETEONE SP.                                                                 1
480112020500                      ETEONE LONGA                                                               6
4801120205F0                      ETEONE LONGA FRAGS                                                         1
480120010200                      GYPTIS BREVIPALPA                                                          5
480122020000                      SYLLIS SP.                                                                 1
480122020100                      PIONOSYLLIS GIGANTEA                                                       1
480122070200                      EXOGONE GEMMIFERA                                                          1
480122070400                      EXOGONE MOLESTA                                                            1
480123000000                 NEREIDAE                                                                        1
480123040000                      NEREIS SP.                                                                 1
480124010000                      NEPHTYS SP.                                                                2
4801240100F0                      NEPHTYS SP. FRAGS                                                          1
480124010400                      NEPHTYS CORNUTA                     X      X      X      X     'X         14
480124010500                      NEPHTYS PUNCTATA                                                           4
480124011100                      NEPHTYS FERRUGINEA                                                         4
480126000000                 GLYCERIDAE                                                                      2
480126010100                      GLYCERA CAPITATA                                                           4
480127010100                      GLYCINDE PICTA                      X                                     10
480127010300                      GLYCINDE ARMIGERA                                                          4
480127020200                      GONIADA MACULATA                                                           1
480128010300                      ONUPHIS IRIDESCENS                                                         3
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                                                                                         03/25/79       PAGE    3
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

LIST OF ALL TAXONOMIC GROUPS FOUND                                    CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
                                                                      CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION
CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION           CRIT1  CRIT2  CRIT3  CRIT4  CRIT5      STA OCC

TAXON CODE               TAXON NAME

480130000OF0             LUMBRINERIDAE FRAGS                                                                   2
480130010OF0                   LUMBRINERIS SP. FRAGS.                                                          1
480130010100                   LUMBRINERIS BICIRRATA                    X      X             X                 9
480130011900                   LUMBRINERIS LUTI                                                                1
4801390000F0             ORBINIIDAE FRAGS                                                                      1
490139010000                   HAPLOSCOLOPLOS SP.                                                              8
490139010200                   HAPLOSCOLOPLOS ELONGATUS                                                        4
490139030000                   SCOLOPLOS FULIGINOSA                                                            1
480140000000             PARAONIDAE                                                                            3
490140020400                   ARICIDEA JEFFREYSII                                                             2
480142000000             SPIONIDAE                                                                             3
4801420000F0             SPIONIDAE FRAGS                                                                       1
480142020000                   LAONICE SP.                                                                     5
480142040000                   POLYDORA SP.                                                                    1
480142040500                   POLYDORA CILIATA                                                                1
480142041500                   POLYDORA LIMICOLA                                                               2
480142050000                   PRIONOSPIO SP.                           X      X             X                11
480142050100                   PRIONOSPIO MALMGRENI                                                            6
480142050200                   PRIONOSPIO CIRRIFERA                                                            4
480142070100                   SPIO FILICORNIS                                                                 1
480142100000                   SPIOPHANES SP.                                                                  5
480142100100                   SPIOPHANES BOMBYX                                                               5
480142100200                   SPIOPHANES KROYERI                                                              1
480142100300                   SPIOPHANES CIRRATA                                                              5
480143010200                   MAGELONA PACIFICA                                                               1
480143010500                   MAGELONA LONGICORNIS                     X      X             X                 9
480149000000             CIRRATULIDAE                                          X                               5
480149030000                   THARYX SP.                                                                      1
4801490400F0                   CHAETOZONE SP. FRAGS                                                            5
490149040100                   CHAETOZONE SETOSA                                                               1
480152010300                   BRADA INHABILIS                          X      X      X      X      X         10
480155010100                   SCALIBREGMA INFLATUM                     X                                      9
480156010100                   AMMOTRYPANE AULOGASTER                                                          4
480158000000             CAPITELLIDAE                                                                          3
4801580000F0             CAPITELLIDAE FRAGS                                   X                                7
480158010100                   CAPITELLA CAPITATA                                                              4
480158020000                   HETEROMASTUS SP. FRAGS                          X      X      X      X          8
480158020100                   HETEROMASTUS FILIFORMIS                                                         1
490158020200                   HETEROMASTUS GIGANTEUS                                                          3
480158030000                   NOTOMASTUS SP.                                                                  3
480158030600                   NOTOMASTUS LAFRIATUS                                 X             X            3
480161000000             MALDANIDAE                                                                            1
4801610000F0             MALDANIDAE FRAGS.                                                                     4
480161080100                   AXIOTHELLA CATENATA                                                             1
480161090200                   PRAXILLELLA PRAETERMISSA                                                        1
4801611002F0                   RHODINE GRACILIOR                                                               1
480162010200                   OWENIA FUSIFORMIS                                                               1
480162020100                   MYRIOCHELE HEERI                                                                2
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                                                                                          03/25/79        PAGE    4
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS        CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION    CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION
                                                              CRIT1  CRIT2  CRIT3  CRIT4  CRIT5     STA OCC
TAXON CODE         TAXON NAME

480163010200                 IDANTHYRSUS ARMATUS                                                       3
480164030300                 PECTINARIA GRANULATA                                                      1
480165000000             AMPHARETIDAE                                                                  3
480165020000                 AMPHARETE SP.                                                             1
480165020100                 AMPHARETE ARCTICA                                                         5
480165040100                 LYSIPPE LABIATA                                                           3
480165050100                 MELINNA CRISTATA                                                          2
480167010100                 TEREBELLIDES STROEMII                                                     1
480168000000             SARELLIDAE                                                                    1
4801680000F0             SARELLIDAE FRAGS.                                                             1
480168010300                 CHONE CINCTA                                                              4
480168140100                 LAONOME KROYERI                                                           2
480170000000             SERPULIDAE                                                                    1
480170010200                 CHITINOPOMA GROENLANDICA                                                  1
480170040000                 SERPULA SP.                                                               1
480170050300                 SPIRORBIS SEMIDENTATUS                                                    1
480175010100                 COSSURA LONGOCIRRATA                                                      3
480200000000         OLIGOCHAETA                                                                       1
490300000000         POLYPLACOPHORA                                                                    1
490400000000         PELECYPODA                                                                        2
4904000000F0         PELECYPODA FRAGS.                                                                 4
490402020100                 NUCULA TENUIS                                                             6
490403000000             NUCULANIDAE                                                                   3
490403020000                 NUCULANA SP.                                                              1
490403020300                 NUCULANA FOSSA                                  X             X           6
490403040000                 TINDARIA SP.                                                              3
490403050000                 YOLDIA SP.                                                                3
490403050700                 YOLDIA THRACIAEFORMIS                           X                         2
490403060000                 YOLDIELLA SP.                                                             1
490407020100                 CRENELLA DESSUCATA                                                        2
490407060000                 MODIOLUS SP.                                                              1
490407060100                 MODIOLUS MODIOLUS                                                         1
490410010100                 PODODESMUS MACROCHISMA                                                    1
490414000000             LUCINIDAE                                                                     1
490415020000                 AXINOPSIDA SP.                   X      X       X      X                 12
490415030100                 THYASIRA FLEXUOSA                                                         4
490416010000                 DIPLODONTA SP.                                                            1
490416010200                 DIPLODONTA ALEUTICA                                                       1
490417000000             KELLIIDAE                                                                     1
490418010000                 MYSELLA SP.                                                               1
490420010000                 CLINOCARDIUM SP.                                                          2
490420010100                 CLINOCARDIUM CILIATUM                           X             X           1
490420020100                 SERRIPES GROENLANDICUS                                                    1
490421050100                 PSEPHIDIA LORDI                                                           1
490423010000                 SPISULA SP.                                     X             X           3
490423010100                 SPISULA POLYNYMA                                                          1
490424010000                 MACOMA SP.                                      X             X           5
490424010100                 MACOMA CALCAREA                                 X             X           5
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                        03/25/79       PAGE    5

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS                    CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION                CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION

TAXON CODE          TAXON NAME                                            CRIT1  CRIT2  CRIT3  CRIT4  CRIT5      STA OCC

490424010300                 MACOMA BROTA                                               X             X          5
490424010700                 MACOMA MOESTA MOESTA                                                                [illegible]
490424011300                 MACOMA CARLOTTENSIS                                                                 [illegible]
490424020100                 TELLINA LUTEA                                                                       [illegible]
490428000000             MYIDAE                                                                                  2
490428020000                 MYA SP.                                                                             3
490429020000                 HIATELLA SP.                                                                        [illegible]
490433020000                 LYONSIA SP.                                                                         [illegible]
490435020000                 THRACIA SP.                                                                         [illegible]
490435020500                 THRACIA BERINGI                                                                     [illegible]
490500000000           GASTROPODA                                                                                4
4905000000F0           GASTROPODA FRAGS                                                                          [illegible]
490504010000                 ACMAEA SP.                                                                          [illegible]
490504020000                 COLISELLA SP.                                                                       [illegible]
490505010100                 CRYPTOBRANCHIA CONCENTRICA                                                          [illegible]
490506040000                 SOLARIELLA SP.                                                                      [illegible]
490506040200                 SOLARIELLA OBSCURA                                                                  [illegible]
490507020100                 MOELLERIA QUADRAI                                                                   [illegible]
490511010000                 SOLARIELLA SP.                                                                      [illegible]
490511030000                 CINGULA SP.                                                                         [illegible]
490530040000                 TROPHONOPSIS SP.                                                                    [illegible]
490541040000                 OENOPOTA SP.                                                                        [illegible]
490545010000                 RETUSA SP.                                                                          [illegible]
490576010000                 SIPHONARIA SP.                                                                      [illegible]
530000000000      CRUSTACEA                                                             X                        [illegible]
530200000000           ANOSTRACA                                                                                 [illegible]
531200000000           CYCLOPOIDA                                                                                [illegible]
531802010000                 BALANUS SP.                                                X             X          [illegible]
531802010400                 BALANUS CRENATUS                                    X      X      X      X          [illegible]
532800000000           CUMACEA                                                                                   [illegible]
532804030400                 EUDORELLOPSIS DEFORMIS                                                              [illegible]
533100000000           AMPHIPODA                                                                                 [illegible]
533102010100                 AMPELISCA MACROCEPHALA                                                              [illegible]
533134140000                 HIPPOMEDON                                                                          [illegible]
533134210000                 LEPIDEPECREUM SP.                                                                   [illegible]
533134290000                 ORCHOMENE SP.                                                                       [illegible]
533137080000                 MONOCULODES SP.                                                                     [illegible]
533142070000                 PARAPHOXUS SP.                                                                      [illegible]
533300000000           DECAPODA                                                                                  [illegible]
533304010600                 PANDALUS HYPSINOTUS                                                                 [illegible]
533311000000             PAGURIDAE                                                                               [illegible]
533311020000                 PAGURUS SP.                                                                         [illegible]
533317010100                 OREGONIA GRACILIS                                                                   [illegible]
533321030000                 PINNIXA SP.                                                                         [illegible]
590101010100                 GOLFINGIA MARGARITACEA                                                              [illegible]
590101020100                 PHASCOLION STROMBI                                                                  [illegible]
680201010100                 DENDRASTER EXCENTRICUS                                                              [illegible]
680204000000             STRONGYLOCENTROTIDAE                                                  X                 [illegible]
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                       03/25/79      PAGE    6

LIST OF ALL TAXONOMIC GROUPS FOUND

CRITERIA 1- TAXON OCCURS IN 50 PCT OR MORE OF STATIONS          CRITERIA 4- ABUNDANT WRT NO. INDIVIDUALS AT SOME STATION
CRITERIA 2- AT LEAST 10 PCT OF INDIVIDUALS AT SOME STATION      CRITERIA 5- ABUNDANT WRT TOTAL BIOMASS AT SOME STATION
CRITERIA 3- AT LEAST 10 PCT OF WET BIOMASS AT SOME STATION

TAXON CODE              TAXON NAME                              CRIT1  CRIT2  CRIT3  CRIT4  CRIT5     STA OCC

680204010100                  ALLOCENTROTUS FRAGILIS                                                    2
680309000000               OPHIURIDAE                                                                   4
6803090000F0               OPHIURIDAE FRAGS                                                             3
791613000000               PHOLIDIDAE                                          X             X          2
999900000000       NO FAUNA COLLECTED IN THIS GRAB                     X       X      X      X          3
999999999900        UNIDENTIFIED                                                                        1
9999999999F0        UNIDENTIFIED FRAGS.                                                                 2

TOTAL NUMBER OF TAXONS = 198
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                                                                                    03/25/79      PAGE    7
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
                                                       PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 261      STATION 0A
                                                         SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE          TAXON NAME                            DATE    NO.    NO.  PCT    GRAMS   PCT    NO.   WWGT   BIT CRITERIA

4801000000F0    POLYCHAETA FRAG.                        06/12/78   1      1  1.10   0.001   0.18     5   0.005   X

480124010400                NEPHTYS CORNUTA             06/12/78   2     32 35.16   0.178  31.96   160   0.890   X X X X X
480124010400                NEPHTYS CORNUTA             06/12/78   1     50 54.95   0.227  40.75   250   1.135   X X X X X
                                                           SUBTOTAL      82 90.11   0.405  72.71   410   2.025

480155010100                SCALIBREGMA INFLATUM        06/12/78   1      4  4.40   0.109  19.57    20   0.545   X X X X X
480155010100                SCALIBREGMA INFLATUM        06/12/78   2      1  1.10   0.023   4.13     5   0.115   X X X X X
                                                           SUBTOTAL       5  5.49   0.132  23.70    25   0.660

480156010100                AMMOTRYPANE AULOGASTER      06/12/78   1      1  1.10   0.017   3.05     5   0.085   X

490415020000                AXINOPSIDA SP.              06/12/78   1      1  1.10   0.001   0.18     5   0.005   X X X X
490415020000                AXINOPSIDA SP.              06/12/78   2      1  1.10   0.001   0.18     5   0.005   X X X X
                                                           SUBTOTAL       2  2.20   0.002   0.36    10   0.010

                                                       STATION TOTAL     91         0.557          455   2.785

                                                       SIMPSON INDEX 0.813675          SHANNON DIVERSITY INDEX 0.436305
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                                                                                         03/25/79      PAGE    8
 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
                                                     PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
 CRUISE 261      STATION 08
                                                        SAMPLE    SAMP       COUNT      WET WEIGHT     PER SQ METER
                                                         DATE      NO.     NO.   PCT    GRAMS   PCT     NO.   WWGT    BIT CRITERIA
 TAXON CODE          TAXON NAME

 310431000000          FORAMINIFERA                     06/12/78    1     116 10.55    0.335  0.34     232   0.670      X    X
 310431000000          FORAMINIFERA                     06/12/78    2     113 10.27    0.289  0.29     226   0.578      X    X
 310431000000          FORAMINIFERA                     06/12/78    5      96  8.73    0.224  0.23     192   0.448      X    X
                                                           SUBTOTAL       325 29.55    0.848  0.86     650   1.696

 400000000000  RHYNCHOCOELA                             06/12/78    5       1  0.09    0.004  0.00       2   0.008

 4801000000F0        POLYCHAETA FRAG.                   06/12/78    4       1  0.09    0.040  0.04       2   0.080    X
 4801000000F0        POLYCHAETA FRAG.                   06/12/78    2       1  0.09    0.077  0.08       2   0.154    X
 4801000000F0        POLYCHAETA FRAG.                   06/12/78    3       1  0.09    0.045  0.05       2   0.090    X
                                                           SUBTOTAL         3  0.27    0.162  0.16       6   0.324

 480101000000           POLYNOIDAE                      06/12/78    2       2  0.18    0.011  0.01       4   0.022

 480101080600              HARMOTHOE IMBRICATA          06/12/78    3       1  0.09    0.072  0.07       2   0.144
 480101080600              HARMOTHOE IMBRICATA          06/12/78    4       1  0.09    0.032  0.03       2   0.064
                                                           SUBTOTAL         2  0.18    0.104  0.11       4   0.208

 480101170100              HESPERONE COMPLANATA         06/12/78    1       1  0.09    0.015  0.02       2   0.030

 480105030000              STHENELAIS SP.               06/12/78    1       3  0.27    1.181  1.20       6   2.362
 480105030000              STHENELAIS SP.               06/12/78    3       2  0.18    0.393  0.40       4   0.786
 480105030000              STHENELAIS SP.               06/12/78    2       1  0.09    0.009  0.01       2   0.018
 480105030000              STHENELAIS SP.               06/12/78    4       1  0.09    0.230  0.23       2   0.460
 480105030000              STHENELAIS SP.               06/12/78    5       1  0.09    0.210  0.21       2   0.420
                                                           SUBTOTAL         8  0.73    2.023  2.05      16   4.046

 480105040000              SIGALION SP.                 06/12/78    4       1  0.09    0.001  0.00       2   0.002

 480124010600              NEPHTYS SP.                  06/12/78    4       1  0.09    0.046  0.05       2   0.092

 480124011100              NEPHTYS FERRUGINEA           06/12/78    4       5  0.45    0.081  0.08      10   0.162
 480124011100              NEPHTYS FERRUGINEA           06/12/78    5       2  0.18    0.106  0.11       4   0.212
 480124011100              NEPHTYS FERRUGINEA           06/12/78    2       2  0.18    0.060  0.06       4   0.120
 480124011100              NEPHTYS FERRUGINEA           06/12/78    3       3  0.27    0.094  0.10       6   0.188
 480124011100              NEPHTYS FERRUGINEA           06/12/78    1       2  0.18    0.101  0.10       4   0.202
                                                           SUBTOTAL        14  1.27    0.442  0.45      28   0.884

 480127010100              GLYCINDE PICTA               06/12/78    1       2  0.18    0.020  0.02       4   0.040    X
 480127010100              GLYCINDE PICTA               06/12/78    3       2  0.18    0.014  0.01       4   0.028    X
 480127010100              GLYCINDE PICTA               06/12/78    2       2  0.18    0.009  0.01       4   0.018    X
 480127010100              GLYCINDE PICTA               06/12/78    5       7  0.64    0.133  0.13      14   0.266    X
                                                           SUBTOTAL        13  1.18    0.176  0.18      26   0.352

 480127010300              GLYCINDE ARMIGERA            06/12/78    2       1  0.09    0.051  0.05       2   0.102
 480127010300              GLYCINDE ARMIGERA            06/12/78    1       2  0.18    0.083  0.08       4   0.166
                                                           SUBTOTAL         3  0.27    0.134  0.14       6   0.268

 480128010300              ONUPHIS IRIDESCENS           06/12/78    2       1  0.09    0.260  0.26       2   0.520
 480128010300              ONUPHIS IRIDESCENS           06/12/78    4       1  0.09    0.274  0.28       2   0.548
                                                           SUBTOTAL         2  0.18    0.534  0.54       4   1.068
 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                         03/25/79        PAGE    9
CRUISE 261      STATION OB                                PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                          SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE          TAXON NAME                             DATE     NO.   NO.  PCT    GRAMS   PCT     NO.   WWGT    BIT CRITERI/
4901300000F0          LUMBRINERIDAE FRAGS                06/12/78    2     1  0.09   0.031  0.03       2  0.062

480130010100               LUMBRINERIS BICIRRATA         06/12/78    3     2  0.18   0.445  0.45       4  0.890
480130010100               LUMBRINERIS BICIRRATA         06/12/78    1     1  0.09   0.363  0.37       2  0.726
480130010100               LUMBRINERIS BICIRRATA         06/12/78    4     2  0.18   1.224  1.24       4  2.448
480130010100               LUMBRINERIS BICIRRATA         06/12/78    5     3  0.27   1.655  1.68       6  3.310
                                                             SUBTOTAL      8  0.73   3.687  3.74      16  7.374

480139000OF0          ORBINIDAE FRAGS                    06/12/78    5     1  0.09   0.027  0.03       2  0.054

480139010200               HAPLOSCOLOPLOS ELONGATUS      06/12/78    5    11  1.00   0.201  0.20      22  0.402
483139010200               HAPLOSCOLOPLOS ELONGATUS      06/12/78    4     3  0.27   0.014  0.01       6  0.028
490139010200               HAPLOSCOLOPLOS ELONGATUS      06/12/78    1     8  0.73   0.262  0.27      16  0.524
480139010200               HAPLOSCOLOPLOS ELONGATUS      06/12/78    3     4  0.36   0.050  0.05       8  0.100
490139010200               HAPLOSCOLOPLOS ELONGATUS      06/12/78    2     9  0.82   0.051  0.05      18  0.102
                                                             SUBTOTAL     35  3.18   0.578  0.59      70  1.156

480139030000               SCOLOPLOS FULIGINOSA          06/12/78    5     1  0.09   0.001  0.00       2  0.002

4801420000F0          SPIONIDAE FRAGS                    06/12/78    5     1  0.09   0.005  0.01       2  0.010
4801420000F0          SPIONIDAE FRAGS                    06/12/78    2     1  0.09   0.027  0.03       2  0.054
                                                             SUBTOTAL      2  0.18   0.032  0.03       4  0.064

480142040000               POLYDORA SP.                  06/12/78    5     1  0.09   0.001  0.00       2  0.002

480142050000               PRIONOSPIO SP.                06/12/78    2     1  0.09   0.001  0.00       2  0.002

480142050100               PRIONOSPIO MALMGRENI          06/12/78    1     1  0.09   0.001  0.00       2  0.002   X X   X

480142100100               SPIOPHANES BOMBYX             06/12/78    1     5  0.45   0.046  0.05      10  0.092
480142100100               SPIOPHANES BOMBYX             06/12/78    2     5  0.45   0.026  0.03      10  0.052
480142100100               SPIOPHANES BOMBYX             06/12/78    3    10  0.91   0.181  0.18      20  0.362
480142100100               SPIOPHANES BOMBYX             06/12/78    5    11  1.00   0.272  0.28      22  0.544
490142100100               SPIOPHANES BOMBYX             06/12/78    4     2  0.18   0.005  0.01       4  0.010
                                                             SUBTOTAL     33  3.00   0.530  0.54      66  1.060

480143010500               MAGELONA LONGICORNIS          06/12/78    4     6  0.55   0.047  0.05      12  0.094
490143010500               MAGELONA LONGICORNIS          06/12/78    5     8  0.73   0.044  0.04      16  0.088
480143010500               MAGELONA LONGICORNIS          06/12/78    3     4  0.36   0.022  0.02       8  0.044
490143010500               MAGELONA LONGICORNIS          06/12/78    2     9  0.82   0.044  0.04      18  0.088
480143010500               MAGELONA LONGICORNIS          06/12/78    1     5  0.45   0.040  0.04      10  0.080
                                                             SUBTOTAL     32  2.91   0.197  0.20      64  0.394

480149000000          CIRRATULIDAE                       06/12/78    1     7  0.64   0.046  0.05      14  0.092   X X   X
480149000000          CIRRATULIDAE                       06/12/78    2    16  1.45   0.078  0.08      32  0.156   X X   X
480149000000          CIRRATULIDAE                       06/12/78    3    19  1.73   0.095  0.10      38  0.190   X X   X
480149000000          CIRRATULIDAE                       06/12/78    5    20  1.82   0.138  0.14      40  0.276   X X   X
480149000000          CIRRATULIDAE                       06/12/78    4     7  0.64   0.050  0.05      14  0.100   X X   X
                                                             SUBTOTAL     69  6.27   0.407  0.41     138  0.814
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
CRUISE 261      STATION 08                               PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                          SAMPLE    SAMP     COUNT       WET WEIGHT      PER SQ METER
TAXON CODE            TAXON NAME                           DATE      NO.    NO.  PCT     GRAMS   PCT     NO.    WWGT    BIT CRITERIA
480149030000                    THARYX SP.                06/12/78    1      1  0.09     0.005  0.01       2   0.010      X
480156010100                    AMMOTRYPANE AULOGASTER    06/12/78    1      1  0.09     0.001  0.00       2   0.002    X
480161000000              MALDANIDAE                      06/12/78    3      4  0.36     0.702  0.71       8   1.404        X   X
480161000000              MALDANIDAE                      06/12/78    4      1  0.09     0.104  0.11       2   0.208        X   X
                                                             SUBTOTAL        5  0.45     0.806  0.82      10   1.612
480161080100                    AXIOTHELLA CATENATA       06/12/78    2      1  0.09     0.240  0.24       2   0.480
480161080100                    AXIOTHELLA CATENATA       06/12/78    1      1  0.09     0.103  0.10       2   0.206
                                                             SUBTOTAL        2  0.18     0.343  0.35       4   0.686
480165000000              AMPHARETIDAE                    06/12/78    5      1  0.09     0.002  0.00       2   0.004
490403040000                    TINDARIA SP.              06/12/78    1      1  0.09     0.001  0.00       2   0.002
490407020100                    CRENELLA DESSUCATA        06/12/78    3      3  0.27     0.035  0.04       6   0.070
490407020100                    CRENELLA DESSUCATA        06/12/78    5      1  0.09     0.004  0.00       2   0.008
490407020100                    CRENELLA DESSUCATA        06/12/78    4      1  0.09     0.005  0.01       2   0.010
                                                             SUBTOTAL        5  0.45     0.044  0.04      10   0.088
490415020000                    AXINOPSIDA SP.            06/12/78    4     24  2.18     0.441  0.45      48   0.882    X X X X
490415020000                    AXINOPSIDA SP.            06/12/78    5     42  3.82     0.418  0.42      84   0.836    X X X X
490415020000                    AXINOPSIDA SP.            06/12/78    3     45  4.09     0.350  0.36      90   0.700    X X X X
490415020000                    AXINOPSIDA SP.            06/12/78    2     39  3.55     0.392  0.40      78   0.784    X X X X
490415020000                    AXINOPSIDA SP.            06/12/78    1     29  2.64     0.384  0.39      58   0.768    X X X X
                                                             SUBTOTAL      179 16.27     1.985  2.01     358   3.970
490416010200                    DIPLODONTA ALEUTICA       06/12/78    1      1  0.09     0.271  0.28       2   0.542
490416010200                    DIPLODONTA ALEUTICA       06/12/78    4      1  0.09     0.001  0.00       2   0.002
                                                             SUBTOTAL        2  0.18     0.272  0.28       4   0.544
490418010000                    MYSELLA SP.               06/12/78    4      1  0.09     0.002  0.00       2   0.004
490418010000                    MYSELLA SP.               06/12/78    1      3  0.27     0.004  0.00       6   0.008
490418010000                    MYSELLA SP.               06/12/78    2      3  0.27     0.004  0.00       6   0.008
                                                             SUBTOTAL        7  0.64     0.010  0.01      14   0.020
490421050100                    PSEPHIDIA LORDI           06/12/78    3      3  0.27     0.006  0.01       6   0.012
490421050100                    PSEPHIDIA LORDI           06/12/78    1      3  0.27     0.036  0.04       6   0.072
490421050100                    PSEPHIDIA LORDI           06/12/78    4      2  0.18     0.003  0.00       4   0.006
490421050100                    PSEPHIDIA LORDI           06/12/78    5      2  0.18     0.035  0.04       4   0.070
                                                             SUBTOTAL       10  0.91     0.080  0.08      20   0.160
490423010000                    SPISULA SP.               06/12/78    5      7  0.64     0.027  0.03      14   0.054        X   X
490423010000                    SPISULA SP.               06/12/78    4      7  0.64     0.043  0.04      14   0.086        X   X
490423010000                    SPISULA SP.               06/12/78    3      4  0.36    77.422 78.57       8 154.844        X   X
490423010000                    SPISULA SP.               06/12/78    2      3  0.27     0.011  0.01       6   0.022        X   X
                                                             SUBTOTAL       21  1.91    77.503 78.65      42 155.006
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 08

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
490423010100	SPISULA POLYNYMA	06/12/78	1	4	0.36	0.012	0.01	8	0.024	
490424010700	MACOMA MOESTA MOESTA	06/12/78	1	1	0.09	0.420	0.43	2	0.840	
490424010700	MACOMA MOESTA MOESTA	06/12/78	2	5	0.45	1.546	1.57	10	3.092	
		SUBTOTAL		6	0.55	1.966	2.00	12	3.932	
490424020100	TELLINA LUTEA	06/12/78	5	1	0.09	3.083	3.13	2	6.156	
490433020000	LYONSIA SP.	06/12/78	4	1	0.09	0.002	0.00	2	0.004	
490433020000	LYONSIA SP.	06/12/78	3	1	0.09	0.005	0.01	2	0.010	
		SUBTOTAL		2	0.18	0.007	0.01	4	0.014	
490435020000	THRACIA SP.	06/12/78	2	1	0.09	0.177	0.18	2	0.354	
490435020000	THRACIA SP.	06/12/78	5	1	0.09	0.052	0.05	2	0.104	
		SUBTOTAL		2	0.18	0.229	0.23	4	0.458	
490435020500	THRACIA BERINGI	06/12/78	1	1	0.09	0.099	0.10	2	0.198	
490500000000	GASTROPODA	06/12/78	5	2	0.18	0.015	0.02	4	0.030	
490506040000	SOLARIELLA SP.	06/12/78	1	3	0.27	0.013	0.01	6	0.026	
490506040200	SOLARIELLA OBSCURA	06/12/78	2	3	0.27	0.083	0.08	6	0.166	
490506040200	SOLARIELLA OBSCURA	06/12/78	3	2	0.18	0.060	0.06	4	0.120	
490506040200	SOLARIELLA OBSCURA	06/12/78	5	5	0.45	0.073	0.07	10	0.146	
		SUBTOTAL		10	0.91	0.216	0.22	20	0.432	
490511030000	CINGULA SP.	06/12/78	5	2	0.18	0.002	0.00	4	0.004	
490511030000	CINGULA SP.	06/12/78	4	5	0.45	0.004	0.00	10	0.008	
490511030000	CINGULA SP.	06/12/78	3	1	0.09	0.002	0.00	2	0.004	
490511030000	CINGULA SP.	06/12/78	2	18	1.64	0.016	0.02	36	0.032	
490511030000	CINGULA SP.	06/12/78	1	3	0.27	0.002	0.00	6	0.004	
		SUBTOTAL		29	2.64	0.026	0.03	58	0.052	
490541040000	OENOPOTA SP.	06/12/78	2	1	0.09	0.013	0.01	2	0.026	
490541040000	OENOPOTA SP.	06/12/78	1	1	0.09	0.096	0.10	2	0.192	
490541040000	OENOPOTA SP.	06/12/78	3	1	0.09	0.160	0.16	2	0.320	
490541040000	OENOPOTA SP.	06/12/78	5	2	0.18	0.092	0.09	4	0.184	
		SUBTOTAL		5	0.45	0.361	0.37	10	0.722	
490545010000	RETUSA SP.	06/12/78	5	1	0.09	0.005	0.01	2	0.010	
532804030400	EUDORELLOPSIS DEFORMIS	06/12/78	5	9	0.82	0.009	0.01	18	0.018	
532804030400	EUDORELLOPSIS DEFORMIS	06/12/78	4	8	0.73	0.009	0.01	16	0.018	
532804030400	EUDORELLOPSIS DEFORMIS	06/12/78	3	3	0.27	0.003	0.00	6	0.006	
532804030400	EUDORELLOPSIS DEFORMIS	06/12/78	1	11	1.00	0.009	0.01	22	0.018	
532804030400	EUDORELLOPSIS DEFORMIS	06/12/78	2	10	0.91	0.006	0.01	20	0.012	
		SUBTOTAL		41	3.73	0.036	0.04	82	0.072	

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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                           03/25/79      PAGE   12
CRUISE 261        STATION 08                          PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                         SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE             TAXON NAME                         DATE     NO.   NO.  PCT    GRAMS   PCT    NO.   WWGT    BIT CRITERI
533100000000        AMPHIPODA                           06/12/78    4      1  0.09   0.003  0.00      2  0.006

533102010100                 AMPELISCA MACROCEPHALA     06/12/78    4      2  0.18   0.004  0.00      4  0.008
533102010100                 AMPELISCA MACROCEPHALA     06/12/78    5      3  0.27   0.053  0.05      6  0.106
533102010100                 AMPELISCA MACROCEPHALA     06/12/78    1      1  0.09   0.036  0.04      2  0.072
533102010100                 AMPELISCA MACROCEPHALA     06/12/78    3      2  0.18   0.049  0.05      4  0.098
533102010100                 AMPELISCA MACROCEPHALA     06/12/78    2      1  0.09   0.002  0.00      2  0.004
                                                            SUBTOTAL       9  0.82   0.144  0.15     18  0.288

533134140000                 HIPPOMEDON                 06/12/78    2     10  0.91   0.077  0.08     20  0.154
533134140000                 HIPPOMFDON                 06/12/78    3      8  0.73   0.060  0.06     16  0.120
533134140000                 HIPPOMEDON                 06/12/78    1      2  0.18   0.015  0.02      4  0.030
533134140000                 HIPPOMEDON                 06/12/78    5     17  1.55   0.151  0.15     34  0.302
533134140000                 HIPPOMEDON                 06/12/78    4      5  0.45   0.060  0.06     10  0.120
                                                            SUBTOTAL      42  3.82   0.363  0.37     84  0.726

533134290000                 ORCHOMENE SP.              06/12/78    5      2  0.18   0.004  0.00      4  0.008
533134290000                 ORCHOMENE SP.              06/12/78    1      1  0.09   0.003  0.00      2  0.006
533134290000                 ORCHOMENE SP.              06/12/78    2      3  0.27   0.033  0.03      6  0.066
                                                            SUBTOTAL       6  0.55   0.040  0.04     12  0.080

533137080000                 MONOCULODES SP.            06/12/78    5      1  0.09   0.002  0.00      2  0.004

533142070000                 PARAPHOXUS SP.             06/12/78    5     15  1.36   0.046  0.05     30  0.092
533142070000                 PARAPHOXUS SP.             06/12/78    4     10  0.91   0.027  0.03     20  0.054
533142070000                 PARAPHOXUS SP.             06/12/78    2      8  0.73   0.024  0.02     16  0.048
533142070000                 PARAPHOXUS SP.             06/12/78    3      7  0.64   0.023  0.02     14  0.046
533142070000                 PARAPHOXUS SP.             06/12/78    1      4  0.36   0.014  0.01      8  0.028
                                                            SUBTOTAL      44  4.00   0.134  0.14     88  0.268

533300000000        DECAPODA                            06/12/78    2      1  0.09   0.005  0.01      2  0.010

680201010100                 DENDRASTER EXCENTRICUS     06/12/78    2      1  0.09   0.205  0.21      2  0.410

680204000000             STRONGYLOCENTROTIDAE           06/12/78    2     19  1.73   0.032  0.03     38  0.064              X
680204000000             STRONGYLOCENTROTIDAE           06/12/78    3     12  1.09   0.016  0.02     24  0.032              X
680204000000             STRONGYLOCENTROTIDAE           06/12/78    4     21  1.91   0.026  0.03     42  0.052              X
680204000000             STRONGYLOCENTROTIDAE           06/12/78    5     28  2.55   0.037  0.04     56  0.074              X
                                                            SUBTOTAL      80  7.27   0.111  0.11    160  0.222

680204010100                 ALLOCENTROTUS FRAGILIS     06/12/78    1     11  1.00   0.014  0.01     22  0.028

6803090000F0             OPHIURIDAE FRAGS               06/12/78    2      1  0.09   0.406  Q.41      2  0.812
                                                    STATION TOTAL       1100        98.540         2200 197.080
                                                    SIMPSON INDEX 0.131458         SHANNON DIVERSITY INDEX 2.710343
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                                                                                 03/25/79        PAGE   13
 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
                                                    PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
 CRUISE 261        STATION 00
                                                       SAMPLE   SAMP      COUNT       WET WEIGHT    PER SQ METER
 TAXON CODE              TAXON NAME                     DATE     NO.    NO.   PCT     GRAMS   PCT     NO.   WWGT    BIT CRITERIA

 480124010400                   NEPHTYS CORNUTA       05/11/78    5     14  18.67    0.084  29.37    28   0.168    X X X X X
 480124010400                   NEPHTYS CORNUTA       05/11/78    4     23  30.67    0.076  26.57    46   0.152    X X X X X
 490124010400                   NEPHTYS CORNUTA       05/11/78    3     14  18.67    0.067  23.43    28   0.134    X X X X X
 490124010400                   NEPHTYS CORNUTA       05/11/78    2     12  16.00    0.052  18.18    24   0.104    X X X X X
 480124010400                   NEPHTYS CORNUTA       05/11/78    1     11  14.67    0.006   2.10    22   0.012    X X X X X
                                                          SUBTOTAL      74  98.67    0.285  99.65   148   0.570

 533300000000            DECAPODA                     05/11/78    3      1   1.33    0.001   0.35     2   0.002

                                                    STATION TOTAL       75           0.286          150   0.572

                                                    SIMPSON INDEX 0.973333         SHANNON DIVERSITY INDEX 0.070811
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                                                                                                   03/25/79     ' PAGE   14
 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978               PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
 CRUISE 261      STATION 01A                                SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
                                                             DATE     NO.   NO.  PCT     GRAMS   PCT    NO.   WWGT    BIT CRITERIA
TAXON CODE                TAXON NAME
480124010400                    NEPHTYS CORNUTA            05/11/78    2      6 31.58    0.038   5.69    12   0.076    X X X X X
480124010400                    NEPHTYS CORNUTA            05/11/78    5      2 10.53    0.040   5.99     4   0.080    X X X X X
480124010400                    NEPHTYS CORNUTA            05/11/78    4      3 15.79    0.046   6.89     6   0.092    X X X X X
480124010400                    NEPHTYS CORNUTA            05/11/78    3      5 26.32    0.046   6.89    10   0.092    X X X X X
                                                              SUBTOTAL       16 84.21    0.170  25.45    32   0.340
480142100100                    SPIOPHANES BOMBYX          05/11/78    2      1  5.26    0.004   0.60     2   0.008
480158010100                    CAPITELLA CAPITATA         05/11/78    3      1  5.26    0.167  25.00     2   0.334        X
791613000000                PHOLIDIDAE                     05/11/78    2      1  5.26    0.327  48.95     2   0.654        X   X
999900000000 NO FAUNA COLLECTED IN THIS GRAB               05/11/78    1      0  0.      0.      0.       0   0.        X X X X
                                                           STATION TOTAL     19          0.668           38   1.336
                                                           SIMPSON INDEX 0.701754        SHANNON DIVERSITY INDEX 0.609627
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                                                                                                        03/25/79       PAGE   15
 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978              PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 761      STATION 02
                                                            SAMPLE   SAMP      COUNT     WET WEIGHT   PER SQ METER
TAXON CODE          TAXON NAME                               DATE     NO.    NO.  PCT    GRAMS  PCT    NO.   WWGT    BIT CRITERIA
4801000000F0      POLYCHAETA FRAG.                         06/12/78    5      1  0.93    0.005  0.46     3   0.017    X

480124010400                  NEPHTYS CORNUTA              06/12/78    5     35 32.41    0.151 13.92   117   0.503    X X X X X
480124010400                  NEPHTYS CORNUTA              06/12/78    4     44 40.74    0.280 25.81   147   0.933    X X X X X
480124010400                  NEPHTYS CORNUTA              06/12/78    3     20 18.52    0.153 14.10    67   0.510    X X X X X
                                                                SUBTOTAL     99 91.67    0.584 53.82   330   1.947

480155010100                  SCALIBREGMA INFLATUM         06/12/78    3      1  0.93    0.074  6.82     3   0.247    X X X X X
480155010100                  SCALIBREGMA INFLATUM         06/12/78    4      7  6.48    0.422 38.89    23   1.407    X X X X X
                                                                SUBTOTAL      8  7.41    0.496 45.71    27   1.653

                                                          STATION TOTAL     108          1.085         360   3.617

                                                          SIMPSON INDEX 0.844410          SHANNON DIVERSITY INDEX 0.315905
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                        03/25/79      PAGE   16
CRUISE 261      STATION 02A                         PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                      SAMPLE  SAMP     COUNT    WET WEIGHT  PER SQ METER
TAXON CODE           TAXON NAME                        DATE    NO.   NO.  PCT   GRAMS  PCT   NO.   WWGT    BIT CRITERIA
480105010100                PHLOE MINUTA             06/12/78   1      1 14.29  0.001  4.17   10   0.010     X
480124010400                NEPHTYS CORNUTA          06/12/78   1      5 71.43  0.018 75.00   50   0.180   X X X X X
480155010100                SCALIBREGMA INFLATUM     06/12/78   1      1 14.29  0.005 20.83   10   0.050   X X X X X
                                                    STATION TOTAL      7        0.024         70   0.240
                                                    SIMPSON INDEX 0.476190      SHANNON DIVERSITY INDEX 0.796312
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 3

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
4000000000F0	RHYNCHOCOELA FRAGS.	06/11/78	4	1	0.04	8.570	12.76	2	17.140	X X
400000000000	RHYNCHOCOELA	06/11/78	5	3	0.13	0.078	0.12	6	0.156	
400000000000	RHYNCHOCOELA	06/11/78	3	1	0.04	0.009	0.01	2	0.018	
		SUBTOTAL		4	0.17	0.087	0.13	8	0.174	
4900000000F0	ANNELIDA FRAGS	06/11/78	2	1	0.04	0.065	0.10	2	0.130	
4900000000F0	ANNELIDA FRAGS	06/11/78	1	1	0.04	0.092	0.14	2	0.184	
4800000000F0	ANNELIDA FRAGS	06/11/78	4	1	0.04	0.078	0.12	2	0.156	
4800000000F0	ANNELIDA FRAGS	06/11/78	3	1	0.04	0.066	0.10	2	0.132	
		SUBTOTAL		4	0.17	0.301	0.45	8	0.602	
4801000000F0	POLYCHAETA FRAG.	06/11/78	3	1	0.04	0.337	0.50	2	0.674	X
4801000000F0	POLYCHAETA FRAG.	06/11/78	5	1	0.04	0.538	0.80	2	1.076	X
4801000000F0	POLYCHAETA FRAG.	06/11/78	2	1	0.04	0.506	0.75	2	1.012	X
		SUBTOTAL		3	0.13	1.381	2.06	6	2.762	
480101000000	POLYNOIDAE	06/11/78	1	2	0.09	0.006	0.01	4	0.012	
480101000000	POLYNOIDAE	06/11/78	5	1	0.04	0.001	0.00	2	0.002	
		SUBTOTAL		3	0.13	0.007	0.01	6	0.014	
480101080600	HARMOTHOE IMBRICATA	06/11/78	5	2	0.09	0.041	0.06	4	0.082	
480101080600	HARMOTHOE IMBRICATA	06/11/78	2	2	0.09	0.055	0.08	4	0.110	
		SUBTOTAL		4	0.17	0.096	0.14	8	0.192	
480101150200	POLYNOE GRACILIS	06/11/78	5	1	0.04	0.057	0.08	2	0.114	
480105000000	SIGALIONIDAE	06/11/78	5	1	0.04	0.001	0.00	2	0.002	
480105010100	PHLOE MINUTA	06/11/78	5	3	0.13	0.005	0.01	6	0.010	X
480105010100	PHLOE MINUTA	06/11/78	3	1	0.04	0.002	0.00	2	0.004	X
480105010100	PHLOE MINUTA	06/11/78	2	4	0.17	0.007	0.01	8	0.014	X
		SUBTOTAL		8	0.35	0.014	0.02	16	0.028	
480112020500	ETEONE LONGA	06/11/78	5	2	0.09	0.014	0.02	4	0.028	
480120010200	GYPTIS BREVIPALPA	06/11/78	1	1	0.04	0.001	0.00	2	0.002	
4801240100F0	NEPHTYS SP. FRAGS	06/11/78	2	1	0.04	1.131	1.68	2	2.262	
480124010400	NEPHTYS CORNUTA	06/11/78	2	1	0.04	0.005	0.01	2	0.010	X X X X X
480124010500	NEPHTYS PUNCTATA	06/11/78	4	1	0.04	1.409	2.10	2	2.818	
480126010100	GLYCERA CAPITATA	06/11/78	3	2	0.09	0.116	0.17	4	0.232	
480126010100	GLYCERA CAPITATA	06/11/78	2	1	0.04	0.006	0.01	2	0.012	
		SUBTOTAL		3	0.13	0.122	0.18	6	0.244	
480127010100	GLYCINDE PICTA	06/11/78	2	9	0.39	0.050	0.07	18	0.100	X
480127010100	GLYCINDE PICTA	06/11/78	1	3	0.13	0.034	0.05	6	0.068	X
480127010100	GLYCINDE PICTA	06/11/78	3	6	0.26	0.052	0.08	12	0.104	X
480127010100	GLYCINDE PICTA	06/11/78	4	4	0.17	0.083	0.12	8	0.166	X
480127010100	GLYCINDE PICTA	06/11/78	5	11	0.48	0.090	0.13	22	0.180	X
		SUBTOTAL		33	1.43	0.309	0.46	66	0.618	

DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 3

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
480127010300	GLYCINDE ARMIGERA	06/11/78	3	3	0.13	0.044	0.07	6	0.088	
480127010300	GLYCINDE ARMIGERA	06/11/78	1	1	0.04	0.004	0.01	2	0.008	
		SUBTOTAL		4	0.17	0.048	0.07	8	0.096	
480127020200	GONIADA MACULATA	06/11/78	5	1	0.04	0.029	0.04	2	0.058	
480128010300	ONUPHIS IRIDESCENS	06/11/78	5	1	0.04	0.008	0.01	2	0.016	
4801300100F0	LUMBRINERIS SP. FRAGS.	06/11/78	2	1	0.04	0.175	0.26	2	0.350	
480130011900	LUMBRINERIS LUTI	06/11/78	2	54	2.34	0.241	0.36	108	0.482	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	1	51	2.21	0.376	0.56	102	0.752	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	5	84	3.64	0.751	1.12	168	1.502	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	3	71	3.08	0.860	1.28	142	1.720	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	4	53	2.30	0.450	0.67	106	0.900	X X X
		SUBTOTAL		313	13.57	2.678	3.99	626	5.356	
480139010000	HAPLOSCOLOPLOS SP.	06/11/78	2	2	0.09	0.016	0.02	4	0.032	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	1	1	0.04	0.035	0.05	2	0.070	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	4	1	0.04	0.013	0.02	2	0.026	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	3	2	0.09	0.014	0.02	4	0.028	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	5	1	0.04	0.016	0.02	2	0.032	
		SUBTOTAL		5	0.22	0.078	0.12	10	0.156	
480139030000	SCOLOPLOS FULIGINOSA	06/11/78	4	17	0.74	0.148	0.22	34	0.296	
480139030000	SCOLOPLOS FULIGINOSA	06/11/78	1	11	0.48	0.051	0.08	22	0.102	
		SUBTOTAL		28	1.21	0.199	0.30	56	0.398	
4801420000F0	SPIONIDAE FRAGS	06/11/78	3	1	0.04	0.035	0.05	2	0.070	
480142040000	POLYDORA SP.	06/11/78	3	2	0.09	0.009	0.01	4	0.018	
480142040000	POLYDORA SP.	06/11/78	4	1	0.04	0.006	0.01	2	0.012	
480142040000	POLYDORA SP.	06/11/78	5	14	0.61	0.045	0.07	28	0.090	
480142040000	POLYDORA SP.	06/11/78	1	1	0.04	0.002	0.00	2	0.004	
480142040000	POLYDORA SP.	06/11/78	2	4	0.17	0.015	0.02	8	0.030	
		SUBTOTAL		22	0.95	0.077	0.11	44	0.154	
480142050000	PRIONOSPIO SP.	06/11/78	2	22	0.95	0.044	0.07	44	0.088	
480142050000	PRIONOSPIO SP.	06/11/78	4	3	0.13	0.010	0.01	6	0.020	
		SUBTOTAL		25	1.08	0.054	0.08	50	0.108	
480142050100	PRIONOSPIO MALMGRENI	06/11/78	4	52	2.25	0.406	0.60	104	0.812	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	3	41	1.78	0.115	0.17	82	0.230	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	5	150	6.50	0.164	0.24	300	0.328	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	2	23	1.00	0.101	0.15	46	0.202	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	1	25	1.08	0.092	0.14	50	0.184	X X X
		SUBTOTAL		291	12.61	0.878	1.31	582	1.756	

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                                                                                              03/25/79      PAGE   19
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
                                                             PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 261      STATION 3
                                                               SAMPLE   SAMP      COUNT      WET WEIGHT    PER SQ METER
TAXON CODE            TAXON NAME                                DATE     NO.    NO.  PCT    GRAMS   PCT    NO.   WWGT    BIT CRITERIA

480142050200                PRIONOSPIO CIRRIFERA               06/11/78   2      3  0.13   0.003  0.00      6  0.006
480142050200                PRIONOSPIO CIRRIFERA               06/11/78   3      1  0.04   0.001  0.00      2  0.002
                                                                   SUBTOTAL      4  0.17   0.004  0.01      8  0.008

480142070100                SPIO FILICORNIS                    06/11/78   3     27  1.17   0.110  0.16     54  0.220
480142070100                SPIO FILICORNIS                    06/11/78   5     46  1.99   0.246  0.37     92  0.492
480142070100                SPIO FILICORNIS                    06/11/78   2     11  0.48   0.088  0.13     22  0.176
                                                                   SUBTOTAL     84  3.64   0.444  0.66    168  0.888

480142100200                SPIOPHANES KROYERI                 06/11/78   1      1  0.04   0.003  0.00      2  0.006

480143010200                MAGELONA PACIFICA                  06/11/78   1      4  0.17   0.015  0.02      8  0.030
480143010200                MAGELONA PACIFICA                  06/11/78   2     11  0.48   0.111  0.17     22  0.222
480143010200                MAGELONA PACIFICA                  06/11/78   5     15  0.65   0.131  0.20     30  0.262
480143010200                MAGELONA PACIFICA                  06/11/78   3     13  0.56   0.128  0.19     26  0.256
480143010200                MAGELONA PACIFICA                  06/11/78   4      4  0.17   0.048  0.07      8  0.096
                                                                   SUBTOTAL     47  2.04   0.433  0.64     94  0.866

480149000000            CIRRATULIDAE                           06/11/78   5     21  0.91   0.037  0.06     42  0.074   X X   X
480149000000            CIRRATULIDAE                           06/11/78   2     16  0.69   0.093  0.14     32  0.186   X X   X
                                                                   SUBTOTAL     37  1.60   0.130  0.19     74  0.260

480149030000                THARYX SP.                         06/11/78   1      7  0.30   0.029  0.04     14  0.058     X
480149030000                THARYX SP.                         06/11/78   4     20  0.87   0.096  0.14     40  0.192     X
480149030000                THARYX SP.                         06/11/78   3     17  0.74   0.078  0.12     34  0.156     X
                                                                   SUBTOTAL     44  1.91   0.203  0.30     88  0.406

4801490400F0                CHAETOZONE SP. FRAGS               06/11/78   2      1  0.04   0.008  0.01      2  0.016

480149040100                CHAETOZONE SETOSA                  06/11/78   5      3  0.13   0.014  0.02      6  0.028

480152010300                BRADA INHABILIS                    06/11/78   3      1  0.04   0.397  0.59      2  0.794

480155010100                SCALIBREGMA INFLATUM               06/11/78   3      2  0.09   0.022  0.03      4  0.044   X X X X X
480155010100                SCALIBREGMA INFLATUM               06/11/78   4      3  0.13   0.168  0.25      6  0.336   X X X X X
480155010100                SCALIBREGMA INFLATUM               06/11/78   5      5  0.22   0.070  0.10     10  0.140   X X X X X
480155010100                SCALIBREGMA INFLATUM               06/11/78   2     11  0.48   0.162  0.24     22  0.324   X X X X X
480155010100                SCALIBREGMA INFLATUM               06/11/78   1      4  0.17   0.070  0.10      8  0.140   X X X X X
                                                                   SUBTOTAL     25  1.08   0.492  0.73     50  0.984

480156010100                AMMOTRYPANE AULOGASTER             06/11/78   1      4  0.17   0.158  0.24      8  0.316   X
480156010100                AMMOTRYPANE AULOGASTER             06/11/78   2      2  0.09   0.049  0.07      4  0.098   X
480156010100                AMMOTRYPANE AULOGASTER             06/11/78   5      2  0.09   0.094  0.14      4  0.188   X
480156010100                AMMOTRYPANE AULOGASTER             06/11/78   4      2  0.09   0.254  0.38      4  0.508   X
480156010100                AMMOTRYPANE AULOGASTER             06/11/78   3      2  0.09   0.048  0.07      4  0.096   X
                                                                   SUBTOTAL     12  0.52   0.603  0.90     24  1.206

4801580000F0            CAPITELLIDAE FRAGS                     06/11/78   3      1  0.04   0.008  0.01      2  0.016
4801580000F0            CAPITELLIDAE FRAGS                     06/11/78   5      1  0.04   0.017  0.03      2  0.034
                                                                   SUBTOTAL      2  0.09   0.025  0.04      4  0.050
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CRUISE 261 STATION 3

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT		WET WEIGHT		PER SQ METER		BIT CRITERIA
				NO.	PCT	GRAMS	PCT	NO.	WWGT	
480158000000	CAPITELLIDAE	06/11/78	2	7	0.30	0.010	0.01	14	0.020	
480158010100	CAPITELLA CAPITATA	06/11/78	1	3	0.13	0.028	0.04	6	0.056	X
480158010100	CAPITELLA CAPITATA	06/11/78	5	3	0.13	0.001	0.00	6	0.002	X
480158010100	CAPITELLA CAPITATA	06/11/78	4	1	0.04	0.005	0.01	2	0.010	X
		SUBTOTAL		7	0.30	0.034	0.05	14	0.068	
480158020000	HETEROMASTUS SP. FRAGS	06/11/78	3	1	0.04	0.002	0.00	2	0.004	
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	3	7	0.30	0.011	0.02	14	0.022	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	4	2	0.09	0.005	0.01	4	0.010	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	5	71	3.08	0.030	0.04	142	0.060	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	2	6	0.26	0.010	0.01	12	0.020	X X X X
		SUBTOTAL		86	3.73	0.056	0.08	172	0.112	
480158030000	NOTOMASTUS SP.	06/11/78	2	2	0.09	0.009	0.01	4	0.018	
480158030000	NOTOMASTUS SP.	06/11/78	1	12	0.52	0.020	0.03	24	0.040	
490158030000	NOTOMASTUS SP.	06/11/78	4	6	0.26	0.020	0.03	12	0.040	
		SUBTOTAL		20	0.87	0.049	0.07	40	0.098	
480158030600	NOTOMASTUS LAERIATUS	06/11/78	3	15	0.65	0.051	0.08	30	0.102	
480158030600	NOTOMASTUS LAERIATUS	06/11/78	5	35	1.52	0.108	0.16	70	0.216	
		SUBTOTAL		50	2.17	0.159	0.24	100	0.318	
480161000000	MALDANIDAE	06/11/78	5	29	1.26	2.311	3.44	58	4.622	X X
480161000000	MALDANIDAE	06/11/78	2	29	1.26	4.429	6.60	58	8.858	X X
		SUBTOTAL		58	2.51	6.740	10.04	116	13.480	
480161080100	AXIOTHELLA CATENATA	06/11/78	1	12	0.52	1.032	1.54	24	2.064	
480161080100	AXIOTHELLA CATENATA	06/11/78	3	13	0.56	1.315	1.96	26	2.630	
480161080100	AXIOTHELLA CATENATA	06/11/78	4	8	0.35	0.828	1.23	16	1.656	
		SUBTOTAL		33	1.43	3.175	4.73	66	6.350	
4801611002F0	RHODINE GRACILIOR	06/11/78	5	1	0.04	0.002	0.00	2	0.004	
490163010200	IDANTHYRSUS ARMATUS	06/11/78	5	11	0.48	0.140	0.21	22	0.280	
480163010200	IDANTHYRSUS ARMATUS	06/11/78	3	3	0.13	0.020	0.03	6	0.040	
		SUBTOTAL		14	0.61	0.160	0.24	28	0.320	
480165020100	AMPHARETE ARCTICA	06/11/78	3	7	0.30	0.009	0.01	14	0.018	
480165020100	AMPHARETE ARCTICA	06/11/78	5	14	0.61	0.010	0.01	28	0.020	
480165020100	AMPHARETE ARCTICA	06/11/78	1	1	0.04	0.001	0.00	2	0.002	
		SUBTOTAL		22	0.95	0.020	0.03	44	0.040	
480165040100	LYSIPPE LABIATA	06/11/78	1	2	0.09	0.013	0.02	4	0.026	
480165040100	LYSIPPE LABIATA	06/11/78	5	4	0.17	0.034	0.05	8	0.068	
480165040100	LYSIPPE LABIATA	06/11/78	3	2	0.09	0.045	0.07	4	0.090	
480165040100	LYSIPPE LABIATA	06/11/78	4	2	0.09	0.023	0.03	4	0.046	
		SUBTOTAL		10	0.43	0.115	0.17	20	0.230	

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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                        03/25/79       PAGE   21
 CRUISE 261       STATION 3                                   PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

 TAXON CODE           TAXON NAME                                SAMPLE  SAMP      COUNT        WET WEIGHT     PER SQ METER
                                                                 DATE    NO.    NO.   PCT     GRAMS   PCT     NO.    WWGT    BIT CRITERIA

 480165050100                  MELINNA CRISTATA                06/11/78   3       1  0.04     0.022  0.03       2   0.044
 480165050100                  MELINNA CRISTATA                06/11/78   1       1  0.04     0.008  0.01       2   0.016
                                                                   SUBTOTAL       2  0.09     0.030  0.04       4   0.060

 480167010100                  TEREBELLIDES STROEMII           06/11/78   2       1  0.04     0.144  0.21       2   0.288

 480168010300                  CHONE CINCTA                    06/11/78   2       9  0.39     0.170  0.25      18   0.340
 480168010300                  CHONE CINCTA                    06/11/78   1       3  0.13     0.026  0.04       6   0.052
 480168010300                  CHONE CINCTA                    06/11/78   3      13  0.56     0.258  0.38      26   0.516
 480168010300                  CHONE CINCTA                    06/11/78   4       3  0.13     0.102  0.15       6   0.204
 490168010300                  CHONE CINCTA                    06/11/78   5      18  0.78     0.311  0.46      36   0.622
                                                                   SUBTOTAL      46  1.99     0.867  1.29      92   1.734

 490400000000            PELECYPODA                            06/11/78   5       1  0.04     1.239  1.85       2   2.478

 490402020100                  NUCULA TENUIS                   06/11/78   5       2  0.09     0.006  0.01       4   0.012
 490402020100                  NUCULA TENUIS                   06/11/78   4       3  0.13     0.008  0.01       6   0.016
 490402020100                  NUCULA TENUIS                   06/11/78   3       9  0.39     0.013  0.02      18   0.026
 490402020100                  NUCULA TENUIS                   06/11/78   1       6  0.26     0.011  0.02      12   0.022
 490402020100                  NUCULA TENUIS                   06/11/78   2       4  0.17     0.011  0.02       8   0.022
                                                                   SUBTOTAL      24  1.04     0.049  0.07      48   0.098

 490403000000               NUCULANIDAE                        06/11/78   4       2  0.09     0.001  0.00       4   0.002

 490403020300                  NUCULANA FOSSA                  06/11/78   4      11  0.48     1.544  2.30      22   3.088         X   X
 490403020300                  NUCULANA FOSSA                  06/11/78   3      37  1.60     2.950  4.39      74   5.900         X  .X
 490403020300                  NUCULANA FOSSA                  06/11/78   5       7  0.30     0.978  1.46      14   1.956         X   X
 490403020300                  NUCULANA FOSSA                  06/11/78   2      18  0.78     1.834  2.73      36   3.668         X   X
 490403020300                  NUCULANA FOSSA                  06/11/78   1      13  0.56     1.378  2.05      26   2.756         X   X
                                                                   SUBTOTAL      86  3.73     8.684 12.93     172  17.368

 490415020000                  AXINOPSIDA SP.                  06/11/78   1     146  6.33     0.834  1.24     292   1.668     X X X X
 490415020000                  AXINOPSIDA SP.                  06/11/78   2     150  6.50     0.600  0.89     300   1.200     X X X X
 490415020000                  AXINOPSIDA SP.                  06/11/78   5      84  3.64     0.473  0.70     168   0.946     X X X X
 490415020000                  AXINOPSIDA SP.                  06/11/78   3     137  5.94     0.734  1.09     274   1.468     X X X X
 490415020000                  AXINOPSIDA SP.                  06/11/78   4     190  8.24     0.974  1.45     380   1.948     X X X X
                                                                   SUBTOTAL     707 30.65     3.615  5.38    1414   7.230

 490415030100                  THYASIRA FLEXUOSA               06/11/78   4       5  0.22     0.153  0.23      10   0.306
 490415030100                  THYASIRA FLEXUOSA               06/11/78   5       1  0.04     0.025  0.04       2   0.050
 490415030100                  THYASIRA FLEXUOSA               06/11/78   2       1  0.04     0.018  0.03       2   0.036
 490415030100                  THYASIRA FLEXUOSA               06/11/78   1       3  0.13     0.186  0.28       6   0.372
                                                                   SUBTOTAL      10  0.43     0.382  0.57      20   0.764

 490420010100                  CLINOCARDIUM CILIATUM           06/11/78   5       6  0.26     9.255 13.78      12  18.510         X   X
 490420010100                  CLINOCARDIUM CILIATUM           06/11/78   3       3  0.13     0.545  0.81       6   1.090         X   X
                                                                   SUBTOTAL       9  0.39     9.800 14.60      18  19.600

 490424010000                  MACOMA SP.                      06/11/78   3       1  0.04     1.697  2.53       2   3.394         X   X
 490424010000                  MACOMA SP.                      06/11/78   5       4  0.17     1.629  2.43       8   3.258         X   X
 490424010000                  MACOMA SP.                      06/11/78   2       3  0.13     2.082  3.10       6   4.164         X   X
                                                                   SUBTOTAL       8  0.35     5.408  8.05      16  10.816
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                                                                                                03/25/79       PAGE   22
 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
                                                          PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
 CRUISE 261      STATION 3
                                                            SAMPLE   SAMP      COUNT      WET WEIGHT     PER SQ METER
 TAXON CODE            TAXON NAME                            DATE     NO.    NO.  PCT     GRAMS   PCT     NO.   WWGT    BIT CRITERIA

 490424010100                   MACOMA CALCAREA           06/11/78    1      4  0.17     2.338  3.48       8   4.676       X   X
 490424010100                   MACOMA CALCAREA           06/11/78    4      1  0.04     1.987  2.96       2   3.974       X   X
                                                              SUBTOTAL       5  0.22     4.325  6.44      10   8.650

 490428000000          MYIDAE                             06/11/78    1      1  0.04     0.012  0.02       2   0.024

 490506040000                   SOLARIELLA SP.            06/11/78    1      1  0.04     0.008  0.01       2   0.016
 490506040000                   SOLARIELLA SP.            06/11/78    4      2  0.09     0.027  0.04       4   0.054
                                                              SUBTOTAL       3  0.13     0.035  0.05       6   0.070

 490506040200                   SOLARIELLA OBSCURA        06/11/78    3      2  0.09     0.022  0.03       4   0.044
 490506040200                   SOLARIELLA OBSCURA        06/11/78    2      4  0.17     0.140  0.21       8   0.280
                                                              SUBTOTAL       6  0.26     0.162  0.24      12   0.324

 532800000000          CUMACEA                            06/11/78    1      1  0.04     0.001  0.00       2   0.002

 532804030400                   EUDORELLOPSIS DEFORMIS    06/11/78    3      1  0.04     0.001  0.00       2   0.002

 533100000000          AMPHIPODA                          06/11/78    3     27  1.17     0.175  0.26      54   0.350
 533100000000          AMPHIPODA                          06/11/78    5     11  0.48     0.021  0.03      22   0.042
 533100000000          AMPHIPODA                          06/11/78    2      1  0.04     0.001  0.00       2   0.002
                                                              SUBTOTAL      39  1.69     0.197  0.29      78   0.394

 533300000000          DECAPODA                           06/11/78    2      1  0.04     0.002  0.00       2   0.004

 590101010100                   GOLFINGIA MARGARITACEA    06/11/78    2      1  0.04     0.013  0.02       2   0.026
 590101010100                   GOLFINGIA MARGARITACEA    06/11/78    1      2  0.09     0.004  0.01       4   0.008
 590101010100                   GOLFINGIA MARGARITACEA    06/11/78    5      6  0.26     0.025  0.04      12   0.050
 590101010100                   GOLFINGIA MARGARITACEA    06/11/78    3      5  0.22     0.108  0.16      10   0.216
                                                              SUBTOTAL      14  0.61     0.150  0.22      28   0.300

 680309000000             OPHIURIDAE                      06/11/78    5      3  0.13     0.926  1.38       6   1.852
 680309000000             OPHIURIDAE                      06/11/78    4      1  0.04     0.001  0.00       2   0.002
                                                              SUBTOTAL       4  0.17     0.927  1.38       8   1.854

 9999999999F0  UNIDENTIFIED FRAGS.                        06/11/78    5      1  0.04     0.056  0.08       2   0.112

                                                          STATION TOTAL   2307          67.145          4614 134.290

                                                          SIMPSON INDEX 0.136190         SHANNON DIVERSITY INDEX 2.746546
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 3A

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA				
330100000000	HYDROZOA	06/11/78	2	1	0.04	0.001	0.00	2	0.002					
4000000000F0	RHYNCHOCOELA FRAGS.	06/11/78	2	1	0.04	0.010	0.02	2	0.020			X		X
4000000000F0	RHYNCHOCOELA FRAGS.	06/11/78	1	1	0.04	0.008	0.01	2	0.016			X		X
		SUBTOTAL		2	0.08	0.018	0.03	4	0.036					
400000000000	RHYNCHOCOELA	06/11/78	1	3	0.11	0.016	0.02	6	0.032					
400000000000	RHYNCHOCOELA	06/11/78	2	1	0.04	0.001	0.00	2	0.002					
400000000000	RHYNCHOCOELA	06/11/78	3	1	0.04	0.001	0.00	2	0.002					
		SUBTOTAL		5	0.19	0.018	0.03	10	0.036					
4801000000F0	POLYCHAETA FRAG.	06/11/78	4	1	0.04	0.017	0.03	2	0.034	X				
4801000000F0	POLYCHAETA FRAG.	06/11/78	2	1	0.04	0.159	0.25	2	0.318	X				
4801000000F0	POLYCHAETA FRAG.	06/11/78	5	1	0.04	0.208	0.32	2	0.416	X				
		SUBTOTAL		3	0.11	0.384	0.59	6	0.768					
480105010100	PHLOE MINUTA	06/11/78	5	3	0.11	0.003	0.00	6	0.006		X			
480105010100	PHLOE MINUTA	06/11/78	2	1	0.04	0.002	0.00	2	0.004		X			
480105010100	PHLOE MINUTA	06/11/78	3	4	0.15	0.006	0.01	8	0.012		X			
		SUBTOTAL		8	0.30	0.011	0.02	16	0.022					
4801120205F0	ETEONE LONGA FRAGS	06/11/78	2	1	0.04	0.001	0.00	2	0.002					
480112020500	ETEONE LONGA	06/11/78	5	1	0.04	0.007	0.01	2	0.014					
480122020000	SYLLIS SP.	06/11/78	2	1	0.04	0.002	0.00	2	0.004					
480123000000	NEREIDAE	06/11/78	3	1	0.04	0.003	0.00	2	0.006					
480124010000	NEPHTYS SP.	06/11/78	1	2	0.08	2.345	3.61	4	4.690					
480124011100	NEPHTYS FERRUGINEA	06/11/78	3	5	0.19	0.031	0.05	10	0.062					
480124011100	NEPHTYS FERRUGINEA	06/11/78	4	3	0.11	0.055	0.08	6	0.110					
480124011100	NEPHTYS FERRUGINEA	06/11/78	2	2	0.08	0.088	0.14	4	0.176					
480124011100	NEPHTYS FERRUGINEA	06/11/78	5	6	0.23	0.022	0.03	12	0.044					
		SUBTOTAL		16	0.61	0.196	0.30	32	0.392					
480127010100	GLYCINDE PICTA	06/11/78	5	6	0.23	0.180	0.28	12	0.360	X				
480127010100	GLYCINDE PICTA	06/11/78	2	8	0.30	0.149	0.23	16	0.298	X				
480127010100	GLYCINDE PICTA	06/11/78	4	10	0.38	0.207	0.32	20	0.414	X				
480127010100	GLYCINDE PICTA	06/11/78	3	10	0.38	0.168	0.26	20	0.336	X				
480127010100	GLYCINDE PICTA	06/11/78	1	5	0.19	0.061	0.09	10	0.122	X				
		SUBTOTAL		39	1.48	0.765	1.18	78	1.530					
480128010300	ONUPHIS IRIDESCENS	06/11/78	3	1	0.04	0.126	0.19	2	0.252					
480130011900	LUMBRINERIS LUTI	06/11/78	3	37	1.41	0.490	0.76	74	0.980	X	X		X	
480130011900	LUMBRINERIS LUTI	06/11/78	4	22	0.84	0.247	0.38	44	0.494	X	X		X	
480130011900	LUMBRINERIS LUTI	06/11/78	2	30	1.14	0.356	0.55	60	0.712	X	X		X	
480130011900	LUMBRINERIS LUTI	06/11/78	5	40	1.52	0.486	0.75	80	0.972	X	X		X	
480130011900	LUMBRINERIS LUTI	06/11/78	1	67	2.55	0.690	1.06	134	1.380	X	X		X	
		SUBTOTAL		196	7.45	2.269	3.50	392	4.538					

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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
CRUISE 261      STATION 3A                                    PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                              SAMPLE  SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE      TAXON NAME                                     DATE    NO.   NO.  PCT    GRAMS   PCT    NO.   WWGT    BIT CRITERIA

480139010200              HAPLOSCOLOPLOS ELONGATUS            06/11/78  1      6  0.23   0.125  0.19    12   0.250
480139010200              HAPLOSCOLOPLOS ELONGATUS            06/11/78  5      8  0.30   0.166  0.26    16   0.332
480139010200              HAPLOSCOLOPLOS ELONGATUS            06/11/78  2      7  0.27   0.180  0.28    14   0.360
480139010200              HAPLOSCOLOPLOS ELONGATUS            06/11/78  4      8  0.30   0.356  0.55    16   0.712
480139010200              HAPLOSCOLOPLOS ELONGATUS            06/11/78  3      8  0.30   0.211  0.33    16   0.422
                                                                  SUBTOTAL    37  1.41   1.038  1.60    74   2.076

480140020400              ARICIDEA JEFFREYSII                 06/11/78  3      1  0.04   0.001  0.00     2   0.002
480140020400              ARICIDEA JEFFREYSII                 06/11/78  2      1  0.04   0.002  0.00     2   0.004
                                                                  SUBTOTAL     2  0.08   0.003  0.00     4   0.006

480142040000              POLYDORA SP.                        06/11/78  2      1  0.04   0.003  0.00     2   0.006

480142050100              PRIONOSPIO MALMGRENI                06/11/78  2     11  0.42   0.101  0.16    22   0.202   X X   X
480142050100              PRIONOSPIO MALMGRENI                06/11/78  3      5  0.19   0.019  0.03    10   0.038   X X   X
480142050100              PRIONOSPIO MALMGRENI                06/11/78  5      4  0.15   0.038  0.06     8   0.076   X X   X
480142050100              PRICNOSPIO MALMGRENI                06/11/78  4      6  0.23   0.043  0.07    12   0.086   X X   X
480142050100              PRIONOSPIO MALMGRENI                06/11/78  1      1  0.04   0.008  0.01     2   0.016   X X   X
                                                                  SUBTOTAL    27  1.03   0.209  0.32    54   0.418

480142070100              SPIO FILICORNIS                     06/11/78  1      3  0.11   0.019  0.03     6   0.038
480142070100              SPIO FILICORNIS                     06/11/78  4      2  0.08   0.003  0.00     4   0.006
480142070100              SPIO FILICORNIS                     06/11/78  5      1  0.04   0.007  0.01     2   0.014
480142070100              SPIO FILICORNIS                     06/11/78  3      1  0.04   0.002  0.00     2   0.004
                                                                  SUBTOTAL     7  0.27   0.031  0.05    14   0.062

480142100000              SPIOPHANES SP.                      06/11/78  5      1  0.04   0.003  0.00     2   0.006

480142100100              SPIOPHANES BOMBYX                   06/11/78  3      1  0.04   0.001  0.00     2   0.002

480143010200              MAGELONA PACIFICA                   06/11/78  4      1  0.04   0.005  0.01     2   0.010
480143010200              MAGELONA PACIFICA                   06/11/78  1      2  0.08   0.032  0.05     4   0.064
                                                                  SUBTOTAL     3  0.11   0.037  0.06     6   0.074

480149000000          CIRRATULIDAE                            06/11/78  1      3  0.11   0.013  0.02     6   0.026   X X   X
480149000000          CIRRATULIDAE                            06/11/78  4      3  0.11   0.022  0.03     6   0.044   X X   X
480149000000          CIRRATULIDAE                            06/11/78  5      6  0.23   0.034  0.05    12   0.068   X X   X
480149000000          CIRRATULIDAE                            06/11/78  3      5  0.19   0.035  0.05    10   0.070   X X   X
480149000000          CIRRATULIDAE                            06/11/78  2      2  0.08   0.004  0.01     4   0.008   X X   X
                                                                  SUBTOTAL    19  0.72   0.108  0.17    38   0.216

480155010100              SCALIBREGMA INFLATUM                06/11/78  2      2  0.08   0.147  0.23     4   0.294   X X X X X
480155010100              SCALIBREGMA INFLATUM                06/11/78  5      2  0.08   0.046  0.07     4   0.092   X X X X X
480155010100              SCALIBREGMA INFLATUM                06/11/78  4      1  0.04   0.026  0.04     2   0.052   X X X X X
480155010100              SCALIBREGMA INFLATUM                06/11/78  1      1  0.04   0.007  0.01     2   0.014   X X X X X
                                                                  SUBTOTAL     6  0.23   0.226  0.35    12   0.452

480156010100              AMMOTRYPANE AULOGASTER              06/11/78  4      1  0.04   0.093  0.14     2   0.186   X
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CRUISE 261 . STATION 3A

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA			
480158010100	CAPITELLA CAPITATA	06/11/78	2	1	0.04	0.003	0.00	2	0.006		X		
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	4	1	0.04	0.002	0.00	2	0.004	X	X	X	X
480158020200	HETEROMASTUS GIGANTEUS	06/11/78	5	1	0.04	0.004	0.01	2	0.008				
480158030600	NOTOMASTUS LAERIATUS	06/11/78	5	3	0.11	0.010	0.02	6	0.020				
480158030600	NOTOMASTUS LAERIATUS	06/11/78	3	1	0.04	0.003	0.00	2	0.006				
		SUBTOTAL		4	0.15	0.013	0.02	8	0.026				
480161000000	MALDANIDAE	06/11/78	3	1	0.04	0.027	0.04	2	0.054		X		X
480161000000	MALDANIDAE	06/11/78	4	1	0.04	0.004	0.01	2	0.008		X		X
		SUBTOTAL		2	0.08	0.031	0.05	4	0.062				
480162020100	MYRIOCHELE HEERI	06/11/78	5	1	0.04	0.021	0.03	2	0.042				
480165020100	AMPHARETE ARCTICA	06/11/78	2	1	0.04	0.005	0.01	2	0.010				
480165020100	AMPHARETE ARCTICA	06/11/78	1	1	0.04	0.002	0.00	2	0.004				
		SUBTOTAL		2	0.08	0.007	0.01	4	0.014				
480165050100	MELINNA CRISTATA	06/11/78	3	1	0.04	0.007	0.01	2	0.014				
480165050100	MELINNA CRISTATA	06/11/78	5	1	0.04	0.004	0.01	2	0.008				
		SUBTOTAL		2	0.08	0.011	0.02	4	0.022				
4801680000F0	SABELLIDAE FRAGS.	06/11/78	1	1	0.04	0.001	0.00	2	0.002				
480168010300	CHONE CINCTA	06/11/78	3	1	0.04	0.018	0.03	2	0.036				
480168010300	CHONE CINCTA	06/11/78	2	2	0.08	0.004	0.01	4	0.008				
		SUBTOTAL		3	0.11	0.022	0.03	6	0.044				
490402020100	NUCULA TENUIS	06/11/78	2	3	0.11	0.013	0.02	6	0.026				
490402020100	NUCULA TENUIS	06/11/78	3	2	0.08	0.006	0.01	4	0.012				
		SUBTOTAL		5	0.19	0.019	0.03	10	0.038				
490403020300	NUCULANA FOSSA	06/11/78	2	3	0.11	0.427	0.66	6	0.854		X		X
490403020300	NUCULANA FOSSA	06/11/78	5	1	0.04	0.053	0.08	2	0.106		X		X
490403020300	NUCULANA FOSSA	06/11/78	1	2	0.08	0.075	0.12	4	0.150		X		X
		SUBTOTAL		6	0.23	0.555	0.86	12	1.110				
490403050000	YOLDIA SP.	06/11/78	4	3	0.11	0.004	0.01	6	0.008				
490403050000	YOLDIA SP.	06/11/78	3	1	0.04	0.001	0.00	2	0.002				
		SUBTOTAL		4	0.15	0.005	0.01	8	0.010				
490415020000	AXINOPSIDA SP.	06/11/78	3	457	17.38	1.469	2.26	914	2.938	X	X	X	X
490415020000	AXINOPSIDA SP.	06/11/78	2	440	16.73	1.247	1.92	880	2.494	X	X	X	X
490415020000	AXINOPSIDA SP.	06/11/78	4	505	19.20	1.927	2.97	1010	3.854	X	X	X	X
490415020000	AXINOPSIDA SP.	06/11/78	5	260	9.89	0.978	1.51	520	1.956	X	X	X	X
490415020000	AXINOPSIDA SP.	06/11/78	1	299	11.37	1.398	2.15	598	2.796	X	X	X	X
		SUBTOTAL		1961	74.56	7.019	10.82	3922	14.038				

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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                  03/25/79          PAGE   26
CRUISE 261       STATION 3A                               PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                           SAMPLE    SAMP       COUNT       WET WEIGHT      PER SQ METER
TAXON CODE             TAXON NAME                           DATE      NO.    NO.   PCT     GRAMS    PCT     NO.    WWGT    BIT CRITERIA
490415030100                 THYASIRA FLEXUOSA             06/11/78    1       9  0.34    0.137   0.21      18   0.274

490420010000                 CLINOCARDIUM SP.              06/11/78    1       2  0.08    0.004   0.01       4   0.008
490420010000                 CLINOCARDIUM SP.              06/11/78    5       1  0.04    0.010   0.02       2   0.020
490420010000                 CLINOCARDIUM SP.              06/11/78    4       2  0.08    0.009   0.01       4   0.018
                                                              SUBTOTAL         5  0.19    0.023   0.04      10   0.046

490420020100                 SERRIPES GROENLANDICUS        06/11/78    3       1  0.04    0.211   0.33       2   0.422

490423010000                 SPISULA SP.                   06/11/78    3      16  0.61    0.032   0.05      32   0.064       X    X
490423010000                 SPISULA SP.                   06/11/78    2       8  0.30    0.010   0.02      16   0.020       X    X
490423010000                 SPISULA SP.                   06/11/78    4       2  0.08    0.003   0.00       4   0.006       X    X
490423010000                 SPISULA SP.                   06/11/78    5      15  0.57    0.031   0.05      30   0.062       X    X
490423010000                 SPISULA SP.                   06/11/78    1       1  0.04    0.002   0.00       2   0.004       X    X
                                                              SUBTOTAL        42  1.60    0.078   0.12      84   0.156

490424010000                 MACOMA SP.                    06/11/78    1       5  0.19    1.284   1.98      10   2.568       X    X
490424010000                 MACOMA SP.                    06/11/78    5       3  0.11    0.024   0.04       6   0.048       X    X
490424010000                 MACOMA SP.                    06/11/78    4       4  0.15    6.757  10.42       8  13.514       X    X
490424010000                 MACOMA SP.                    06/11/78    2       2  0.08    0.003   0.00       4   0.006       X    X
490424010000                 MACOMA SP.                    06/11/78    3       1  0.04    0.      0.         2   0.          X    X
                                                              SUBTOTAL        15  0.57    8.068  12.44      30  16.136

490428020000                 MYA SP.                       06/11/78    3      12  0.46    0.023   0.04      24   0.046
490428020000                 MYA SP.                       06/11/78    2       5  0.19    0.009   0.01      10   0.018
490428020000                 MYA SP.                       06/11/78    4       9  0.34    0.039   0.06      18   0.078
490428020000                 MYA SP.                       06/11/78    5      12  0.46    0.024   0.04      24   0.048
490428020000                 MYA SP.                       06/11/78    1       1  0.04    0.002   0.00       2   0.004
                                                              SUBTOTAL        39  1.48    0.097   0.15      78   0.194

490500000000          GASTROPODA                           06/11/78    1       1  0.04    0.004   0.01       2   0.008

490506040200                 SOLARIELLA OBSCURA            06/11/78    5      15  0.57    1.202   1.85      30   2.404
490506040200                 SOLARIELLA OBSCURA            06/11/78    4       3  0.11    0.088   0.14       6   0.176
490506040200                 SOLARIELLA OBSCURA            06/11/78    2      14  0.53    0.904   1.39      28   1.808
490506040200                 SOLARIELLA OBSCURA            06/11/78    1      20  0.76    0.951   1.47      40   1.902
490506040200                 SOLARIELLA OBSCURA            06/11/78    3      13  0.49    0.779   1.20      26   1.558
                                                              SUBTOTAL        65  2.47    3.924   6.05     130   7.848

490511010000                 SOLARIELLA SP.                06/11/78    2       1  0.04    0.010   0.02       2   0.020
490511010000                 SOLARIELLA SP.                06/11/78    4       1  0.04    0.019   0.03       2   0.038
                                                              SUBTOTAL         2  0.08    0.029   0.04       4   0.058

530200000000          ANOSTRACA                            06/11/78    2       1  0.04    0.001   0.00       2   0.002

531802010000                 BALANUS SP.                   06/11/78    4      20  0.76   36.116  55.67      40  72.232       X    X

532800000000          CUMACEA                              06/11/78    4       1  0.04    0.001   0.00       2   0.002
532800000000          CUMACEA                              06/11/78    5       1  0.04    0.002   0.00       2   0.004
                                                              SUBTOTAL         2  0.08    0.003   0.00       4   0.006
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                                                                                                    03/25/79        PAGE   27
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 261          STATION 3A                                                                     PER SQ METER
                                                               SAMPLE   SAMP      COUNT      WET WEIGHT     NO.    WWGT    BIT CRITERIA
TAXON CODE              TAXON NAME                              DATE     NO.    NO.  PCT     GRAMS  PCT
533100000000          AMPHIPODA                               06/11/78    5     12  0.46     0.036  0.06     24   0.072
533100000000          AMPHIPODA                               06/11/78    4     21  0.80     0.031  0.05     42   0.062
533100000000          AMPHIPODA                               06/11/78    2      5  0.19     0.068  0.10     10   0.136
533100000000          AMPHIPODA                               06/11/78    1      1  0.04     0.001  0.00      2   0.002
533100000000          AMPHIPODA                               06/11/78    3      5  0.19     0.029  0.04     10   0.058
                                                                  SUBTOTAL      44  1.67     0.165  0.25     88   0.330

6803090000F0              OPHIURIDAE FRAGS                    06/11/78    1      1  0.04     0.040  0.06      2   0.080
6803090000F0              OPHIURIDAE FRAGS                    06/11/78    3      1  0.04     0.298  0.46      2   0.596
                                                                  SUBTOTAL       2  0.08     0.338  0.52      4   0.676

680309000000              OPHIURIDAE                          06/11/78    4      2  0.08     0.017  0.03      4   0.034
680309000000              OPHIURIDAE                          06/11/78    3      4  0.15     0.055  0.08      8   0.110
                                                                  SUBTOTAL       6  0.23     0.072  0.11     12   0.144
                                                           STATION TOTAL      2630          64.877           5260 129.754
                                                           SIMPSON INDEX 0.563487           SHANNON DIVERSITY INDEX 1.279623
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                                                                                    ..         03/25/79      PAGE  28
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
                                                       PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 261     STATION 3B
                                                        SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE         TAXON NAME                            DATE    NO.    NO.  PCT    GRAMS   PCT    NO.    WWGT    BIT CRITERIA

4000000000F0  RHYNCHOCOELA FRAGS.                      06/11/78   1      1  0.07    0.192  0.19     2    0.384       X   X
4000000000F0  RHYNCHOCOELA FRAGS.                      06/11/78   5      1  0.07    0.016  0.02     2    0.032       X   X
4000000000F0  RHYNCHOCOELA FRAGS.                      06/11/78   4      1  0.07    0.083  0.08     2    0.166       X   X
4000000000F0  RHYNCHOCOELA FRAGS.                      06/11/78   3      1  0.07    0.097  0.09     2    0.194       X   X
                                                          SUBTOTAL       4  0.27    0.388  0.37     8    0.776

400000000000  RHYNCHOCOELA                             06/11/78   2      3  0.21    0.057  0.06     6    0.114
400000000000  RHYNCHOCOELA                             06/11/78   5      3  0.21    0.043  0.04     6    0.086
400000000000  RHYNCHOCOELA                             06/11/78   1      1  0.07    0.001  0.00     2    0.002
                                                          SUBTOTAL       7  0.48    0.101  0.10    14    0.202

4801000000F0        POLYCHAETA FRAG.                   06/11/78   1      1  0.07    0.048  0.05     2    0.096     X
4801000000F0        POLYCHAETA FRAG.                   06/11/78   5      1  0.07    0.029  0.03     2    0.058     X
4801000000F0        POLYCHAETA FRAG.                   06/11/78   2      1  0.07    0.008  0.01     2    0.016     X
4801000000F0        POLYCHAETA FRAG.                   06/11/78   4      1  0.07    0.027  0.03     2    0.054     X
                                                          SUBTOTAL       4  0.27    0.112  0.11     8    0.224

480101000000             POLYNOIDAE                    06/11/78   4      2  0.14    0.006  0.01     4    0.012
480101000000             POLYNOIDAE                    06/11/78   2      1  0.07    0.030  0.03     2    0.060
480101000000             POLYNOIDAE                    06/11/78   1      1  0.07    0.001  0.00     2    0.002
                                                          SUBTOTAL       4  0.27    0.037  0.04     8    0.074

480101050500                  EUNOE OERSTEDI           06/11/78   4      1  0.07    0.016  0.02     2    0.032

480105000000             SIGALIONIDAE                  06/11/78   5      4  0.27    0.024  0.02     8    0.048

480112010000                  ANAITIDES SP.            06/11/78   4      1  0.07    0.028  0.03     2    0.056

480112020500                  ETEONE LONGA             06/11/78   1      1  0.07    0.002  0.00     2    0.004

480120010200                  GYPTIS BREVIPALPA        06/11/78   1      1  0.07    0.003  0.00     2    0.006
480120010200                  GYPTIS BREVIPALPA        06/11/78   5      1  0.07    0.004  0.00     2    0.008
                                                          SUBTOTAL       2  0.14    0.007  0.01     4    0.014

480124010400                  NEPHTYS CORNUTA          06/11/78   5      2  0.14    0.002  0.00     4    0.004     X X X X X
480124010400                  NEPHTYS CORNUTA          06/11/78   4     11  0.75    0.018  0.02    22    0.036     X X X X X
480124010400                  NEPHTYS CORNUTA          06/11/78   2      3  0.21    0.002  0.00     6    0.004     X X X X X
480124010400                  NEPHTYS CORNUTA          06/11/78   3      2  0.14    0.006  0.01     4    0.012     X X X X X
480124010400                  NEPHTYS CORNUTA          06/11/78   1      2  0.14    0.003  0.00     4    0.006     X X X X X
                                                          SUBTOTAL      20  1.37    0.031  0.03    40    0.062

480124010500                  NEPHTYS PUNCTATA         06/11/78   1      1  0.07    1.514  1.46     2    3.028
480124010500                  NEPHTYS PUNCTATA         06/11/78   2      1  0.07    6.205  5.99     2   12.410
                                                          SUBTOTAL       2  0.14    7.719  7.45     4   15.438

480126010100                  GLYCERA CAPITATA         06/11/78   3      1  0.07    0.065  0.06     2    0.130

480127010100                  GLYCINDE PICTA           06/11/78   4      7  0.48    0.081  0.08    14    0.162     X
480127010100                  GLYCINDE PICTA           06/11/78   2      2  0.14    0.032  0.03     4    0.064     X
480127010100                  GLYCINDE PICTA           06/11/78   5      2  0.14    0.026  0.03     4    0.052     X
480127010100                  GLYCINDE PICTA           06/11,78   1      3  0.21    0.018  0.02     6    0.036     X
                                                          SUBTOTAL      14  0.96    0.157  0.15    28    0.314
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 38

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
480130011900	LUMBRINERIS LUTI	06/11/78	1	22	1.51	0.298	0.29	44	0.596	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	5	40	2.74	0.471	0.45	80	0.942	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	2	24	1.64	0.369	0.36	48	0.738	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	4	28	1.92	0.460	0.44	56	0.920	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	3	21	1.44	0.272	0.26	42	0.544	X X X
		SUBTOTAL		135	9.25	1.870	1.80	270	3.740	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	4	2	0.14	0.087	0.08	4	0.174	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	2	1	0.07	0.004	0.00	2	0.008	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	5	2	0.14	0.042	0.04	4	0.084	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	1	4	0.27	0.176	0.17	8	0.352	
		SUBTOTAL		9	0.62	0.309	0.30	18	0.618	
480139030000	SCOLOPLOS FULIGINOSA	06/11/78	5	1	0.07	0.015	0.01	2	0.030	
480142050100	PRIONOSPIO MALMGRENI	06/11/78	5	[illegible]	0.96	0.148	0.14	28	0.296	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	2	7	0.48	0.124	0.12	14	0.248	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	4	42	2.88	0.425	0.41	84	0.850	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	3	10	0.69	0.088	0.08	20	0.176	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	1	14	0.96	0.165	0.16	28	0.330	X X X
		SUBTOTAL		87	5.96	0.950	0.92	174	1.900	
480142050200	PRIONOSPIO CIRRIFERA	06/11/78	4	1	0.07	0.002	0.00	2	0.004	
480142100200	SPIOPHANES KROYERI	06/11/78	4	6	0.41	0.110	0.11	12	0.220	
480142100200	SPIOPHANES KROYERI	06/11/78	3	3	0.21	0.028	0.03	6	0.056	
480142100200	SPIOPHANES KROYERI	06/11/78	2	3	0.21	0.090	0.09	6	0.180	
480142100200	SPIOPHANES KROYERI	06/11/78	5	4	0.27	0.130	0.13	8	0.260	
480142100200	SPIOPHANES KROYERI	06/11/78	1	4	0.27	0.085	0.08	8	0.170	
		SUBTOTAL		20	1.37	0.443	0.43	40	0.886	
480143010200	MAGELONA PACIFICA	06/11/78	1	2	0.14	0.024	0.02	4	0.048	
480143010200	MAGELONA PACIFICA	06/11/78	5	6	0.41	0.092	0.09	12	0.184	
480143010200	MAGELONA PACIFICA	06/11/78	2	2	0.14	0.015	0.01	4	0.030	
480143010200	MAGELONA PACIFICA	06/11/78	3	2	0.14	0.021	0.02	4	0.042	
		SUBTOTAL		12	0.82	0.152	0.15	24	0.304	
480149000000	CIRRATULIDAE	06/11/78	3	5	0.34	0.026	0.03	10	0.052	X X X
480149000000	CIRRATULIDAE	06/11/78	4	14	0.96	0.122	0.12	28	0.244	X X X
480149000000	CIRRATULIDAE	06/11/78	2	7	0.48	0.070	0.07	14	0.140	X X X
480149000000	CIRRATULIDAE	06/11/78	5	10	0.69	0.107	0.10	20	0.214	X X X
480149000000	CIRRATULIDAE	06/11/78	1	7	0.48	0.052	0.05	14	0.104	X X X
		SUBTOTAL		43	2.95	0.377	0.36	86	0.754	
480155010100	SCALIBREGMA INFLATUM	06/11/78	1	2	0.14	0.070	0.07	4	0.140	X X X X X
480155010100	SCALIBREGMA INFLATUM	06/11/78	5	2	0.14	0.097	0.09	4	0.194	X X X X X
480155010100	SCALIBREGMA INFLATUM	06/11/78	2	2	0.14	0.046	0.04	4	0.092	X X X X X
480155010100	SCALIBREGMA INFLATUM	06/11/78	4	4	0.27	0.273	0.26	8	0.546	X X X X X
480155010100	SCALIBREGMA INFLATUM	06/11/78	3	3	0.21	0.177	0.17	6	0.354	X X X X X
		SUBTOTAL		13	0.89	0.663	0.64	26	1.326	

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CRUISE 261 STATION 38

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
480156010100	AMMOTRYPANE AULOGASTER	06/11/78	4	5	0.34	0.297	0.29	10	0.594	X
480156010100	AMMOTRYPANE AULOGASTER	06/11/78	5	1	0.07	0.063	0.06	2	0.126	X
480156010100	AMMOTRYPANE AULOGASTER	06/11/78	1	2	0.14	0.112	0.11	4	0.224	X
		SUBTOTAL		8	0.55	0.472	0.46	16	0.944	
480158010100	CAPITELLA CAPITATA	06/11/78	1	4	0.27	0.020	0.02	8	0.040	X
480158010100	CAPITELLA CAPITATA	06/11/78	2	3	0.21	0.134	0.13	6	0.268	X
		SUBTOTAL		7	0.48	0.154	0.15	14	0.308	
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	3	7	0.48	0.186	0.18	14	0.372	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	5	7	0.48	0.267	0.26	14	0.534	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/11/78	4	9	0.62	0.096	0.09	18	0.192	X X X X
		SUBTOTAL		23	1.58	0.549	0.53	46	1.098	
480158030000	NOTOMASTUS SP.	06/11/78	4	6	0.41	0.025	0.02	12	0.050	
480158030000	NOTOMASTUS SP.	06/11/78	5	6	0.41	0.027	0.03	12	0.054	
480158030000	NOTOMASTUS SP.	06/11/78	3	3	0.21	0.012	0.01	6	0.024	
480158030000	NOTOMASTUS SP.	06/11/78	2	1	0.07	0.005	0.00	2	0.010	
480158030000	NOTOMASTUS SP.	06/11/78	1	6	0.41	0.021	0.02	12	0.042	
		SUBTOTAL		22	1.51	0.090	0.09	44	0.180	
480161080100	AXIOTHELLA CATENATA	06/11/78	1	9	0.62	1.344	1.30	18	2.688	
480161080100	AXIOTHELLA CATENATA	06/11/78	2	10	0.69	1.300	1.25	20	2.600	
480161080100	AXIOTHELLA CATENATA	06/11/78	3	7	0.48	0.423	0.41	14	0.846	
480161080100	AXIOTHELLA CATENATA	06/11/78	5	14	0.96	1.496	1.44	28	2.992	
480161080100	AXIOTHELLA CATENATA	06/11/78	4	13	0.89	1.804	1.74	26	3.608	
		SUBTOTAL		53	3.63	6.367	6.14	106	12.734	
480163010200	IDANTHYRSUS ARMATUS	06/11/78	4	1	0.07	0.009	0.01	2	0.018	
480165000000	AMPHARETIDAE	06/11/78	1	1	0.07	0.002	0.00	2	0.004	
480165020100	AMPHARETE ARCTICA	06/11/78	4	2	0.14	0.006	0.01	4	0.012	
480165020100	AMPHARETE ARCTICA	06/11/78	5	2	0.14	0.004	0.00	4	0.008	
		SUBTOTAL		4	0.27	0.010	0.01	8	0.020	
480165040100	LYSIPPE LABIATA	06/11/78	4	7	0.48	0.034	0.03	14	0.068	
480165040100	LYSIPPE LABIATA	06/11/78	3	3	0.21	0.005	0.00	6	0.010	
		SUBTOTAL		10	0.69	0.039	0.04	20	0.078	
480168010300	CHONE CINCTA	06/11/78	1	1	0.07	0.021	0.02	2	0.042	
480168010300	CHONE CINCTA	06/11/78	5	2	0.14	0.051	0.05	4	0.102	
		SUBTOTAL		3	0.21	0.072	0.07	6	0.144	
480168140100	LAONOME KROYERI	06/11/78	4	1	0.07	0.002	0.00	2	0.004	
480170000000	SERPULIDAE	06/11/78	4	2	0.14	0.001	0.00	4	0.002	
480175010100	COSSURA LONGOCIRRATA	06/11/78	5	1	0.07	0.001	0.00	2	0.002	

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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261       STATION 38                   PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                               SAMPLE   SAMP     COUNT       WET WEIGHT     PER SQ METER
TAXON CODE              TAXON NAME              DATE     NO.    NO.   PCT    GRAMS    PCT    NO.    WWGT    BIT CRITERIA

490402020100                 NUCULA TENUIS    06/11/78    5       9   0.62    0.013   0.01     18   0.026
490402020100                 NUCULA TENUIS    06/11/78    4       4   0.27    0.005   0.00      8   0.010
490402020100                 NUCULA TENUIS    06/11/78    1       1   0.07    0.001   0.00      2   0.002
490402020100                 NUCULA TENUIS    06/11/78    2       2   0.14    0.002   0.00      4   0.004
                                                 SUBTOTAL        16   1.10    0.021   0.02     32   0.042

490403020300                 NUCULANA FOSSA   06/11/78    2       2   0.14    0.223   0.22      4   0.446        X   X
490403020300                 NUCULANA FOSSA   06/11/78    1       3   0.21    0.252   0.24      6   0.504        X   X
490403020300                 NUCULANA FOSSA   06/11/78    3       3   0.21    0.070   0.07      6   0.140        X   X
490403020300                 NUCULANA FOSSA   06/11/78    4       3   0.21    0.125   0.12      6   0.250        X   X
490403020300                 NUCULANA FOSSA   06/11/78    5       9   0.62    0.877   0.85     18   1.754        X   X
                                                 SUBTOTAL        20   1.37    1.547   1.49     40   3.094

490407060100                 MODIOLUS MODIOLUS 06/11/78   3       1   0.07    0.004   0.00      2   0.008
490407060100                 MODIOLUS MODIOLUS 06/11/78   2       1   0.07    0.001   0.00      2   0.002
                                                 SUBTOTAL         2   0.14    0.005   0.00      4   0.010

490415020000                 AXINOPSIDA SP.   06/11/78    2      72   4.93    0.308   0.30    144   0.616    X X X X
490415020000                 AXINOPSIDA SP.   06/11/78    1     204  13.98    0.737   0.71    408   1.474    X X X X
490415020000                 AXINOPSIDA SP.   06/11/78    3     209  14.32    0.785   0.76    418   1.570    X X X X
490415020000                 AXINOPSIDA SP.   06/11/78    5     253  17.34    0.763   0.74    506   1.526    X X X X
490415020000                 AXINOPSIDA SP.   06/11/78    4     130   8.91    0.698   0.67    260   1.396    X X X X
                                                 SUBTOTAL       868  59.49    3.291   3.18   1736   6.582

490415030100                 THYASIRA FLEXUOSA 06/11/78   4       2   0.14    0.050   0.05      4   0.100
490415030100                 THYASIRA FLEXUOSA 06/11/78   5       1   0.07    0.145   0.14      2   0.290
490415030100                 THYASIRA FLEXUOSA 06/11/78   1       1   0.07    0.429   0.41      2   0.858
                                                 SUBTOTAL         4   0.27    0.624   0.60      8   1.248

490424010100                 MACOMA CALCAREA  06/11/78    1       3   0.21   22.318  21.54      6  44.636        X   X
490424010100                 MACOMA CALCAREA  06/11/78    3       1   0.07    3.807   3.67      2   7.614        X   X
490424010100                 MACOMA CALCAREA  06/11/78    5       3   0.21    4.156   4.01      6   8.312        X   X
490424010100                 MACOMA CALCAREA  06/11/78    4       3   0.21    8.380   8.09      6  16.760        X   X
                                                 SUBTOTAL        10   0.69   38.661  37.31     20  77.322

490424010300                 MACOMA BROTA     06/11/78    3       1   0.07   37.685  36.37      2  75.370        X   X

490504010000                 ACMAEA SP.       06/11/78    5       1   0.07    0.001   0.00      2   0.002

531802010000                 BALANUS SP.      06/11/78    4       1   0.07    0.025   0.02      2   0.050        X   X

533100000000            AMPHIPODA             06/11/78    4       2   0.14    0.004   0.00      4   0.008
533100000000            AMPHIPODA             06/11/78    5       3   0.21    0.013   0.01      6   0.026
533100000000            AMPHIPODA             06/11/78    3       1   0.07    0.002   0.00      2   0.004
                                                 SUBTOTAL         6   0.41    0.019   0.02     12   0.038

533311020000                 PAGURUS SP.      06/11/78    4       3   0.21    0.170   0.16      6   0.340

533321030000                 PINNIXA SP.      06/11/78    4       1   0.07    0.016   0.02      2   0.032
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                           03/25/79      PAGE  32
CRUISE 261      STATION 3B                      PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                  SAMPLE  SAMP      COUNT      WET WEIGHT   PER SO METER
TAXON CODE              TAXON NAME                 DATE    NO.    NO.  PCT    GRAMS  PCT     NO.   WWGT    BIT CRITERI.

680309000000              OPHIURIDAE              06/11/78   4      2  0.14   0.071  0.07      4   0.142
680309000000              OPHIURIDAE              06/11/78   1      2  0.14   0.242  0.23      4   0.484
                                                     SUBTOTAL       4  0.27   0.313  0.30      8   0.626

                                                STATION TOTAL     1459      103.614         2918 207.228

                                                SIMPSON INDEX 0.369512       SHANNON DIVERSITY INDEX 1.849111
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 3BF

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
340000000000	CTENOPHORA	06/12/78	3	1	0.20	1.574	7.91	3	5.247	
400000000OF0	RHYNCHOCOELA FRAGS.	06/12/78	3	1	0.20	0.170	0.85	3	0.567	X X
4801000000F0	POLYCHAETA FRAG.	06/12/78	3	1	0.20	0.050	0.25	3	0.167	X
4801000000F0	POLYCHAETA FRAG.	06/12/78	2	1	0.20	0.049	0.25	3	0.163	X
4801000000F0	POLYCHAETA FRAG.	06/12/78	1	1	0.20	0.046	0.23	3	0.153	X
		SUBTOTAL		3	0.61	0.145	0.73	10	0.483	
480101000000	POLYNOIDAE	06/12/78	3	1	0.20	0.009	0.05	3	0.030	
480101150200	POLYNOE GRACILIS	06/12/78	1	3	0.61	0.020	0.10	10	0.067	
480105010100	PHLOE MINUTA	06/12/78	1	1	0.20	0.002	0.01	3	0.007	X
480112020500	ETEONE LONGA	06/12/78	1	4	0.81	0.006	0.03	13	0.020	
480112020500	ETEONE LONGA	06/12/78	2	2	0.40	0.003	0.02	7	0.010	
		SUBTOTAL		6	1.21	0.009	0.05	20	0.030	
480124010400	NEPHTYS CORNUTA	06/12/78	2	20	4.05	0.040	0.20	67	0.133	X X X X X
480124010400	NEPHTYS CORNUTA	06/12/78	3	22	4.45	0.056	0.28	73	0.187	X X X X X
480124010400	NEPHTYS CORNUTA	06/12/78	1	54	10.93	0.175	0.88	180	0.583	X X X X X
		SUBTOTAL		96	19.43	0.271	1.36	320	0.903	
480127010100	GLYCINDE PICTA	06/12/78	1	2	0.40	0.075	0.38	7	0.250	X
480127010100	GLYCINDE PICTA	06/12/78	3	1	0.20	0.011	0.06	3	0.037	X
480127010100	GLYCINDE PICTA	06/12/78	2	3	0.61	0.016	0.08	10	0.053	X
		SUBTOTAL		6	1.21	0.102	0.51	20	0.340	
480130011900	LUMBRINERIS LUTI	06/12/78	2	1	0.20	0.002	0.01	3	0.007	X X X
480130011900	LUMBRINERIS LUTI	06/12/78	3	4	0.81	0.065	0.33	13	0.217	X X X
480130011900	LUMBRINERIS LUTI	06/12/78	1	2	0.40	0.028	0.14	7	0.093	X X X
		SUBTOTAL		7	1.42	0.095	0.48	23	0.317	
480140000000	PARAONIDAE	06/12/78	2	1	0.20	0.006	0.03	3	0.020	
480140020400	ARICIDEA JEFFREYSII	06/12/78	1	1	0.20	0.002	0.01	3	0.007	•
480142050100	PRIONOSPIO MALMGRENI	06/12/78	1	5	1.01	0.015	0.08	17	0.050	X X X
480142050100	PRIONOSPIO MALMGRENI	06/12/78	2	9	1.82	0.066	0.33	30	0.220	X X X
480142050100	PRIONOSPIO MALMGRENI	06/12/78	3	6	1.21	0.021	0.11	20	0.070	X X X
		SUBTOTAL		20	4.05	0.102	0.51	67	0.340	
480142050200	PRIONOSPIO CIRRIFERA	06/12/78	3	3	0.61	0.002	0.01	10	0.007	
480142050200	PRIONOSPIO CIRRIFERA	06/12/78	1	12	2.43	0.010	0.05	40	0.033	
		SUBTOTAL		15	3.04	0.012	0.06	50	0.040	
480142100200	SPIOPHANES KROYERI	06/12/78	2	1	0.20	0.002	0.01	3	0.007	

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 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                  03/25/79        PAGE   34
 CRUISE 261      STATION 3BF                          PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                        SAMPLE   SAMP    COUNT       WET WEIGHT    PER SQ METER
TAXON CODE            TAXON NAME                         DATE     NO.   NO.  PCT    GRAMS   PCT    NO.    WWGT   BIT CRITERIA

480149000000             CIRRATULIDAE                  06/12/78    2     11  2.23   0.028  0.14     37   0.093   X X   X
480149000000             CIRRATULIDAE                  06/12/78    3     18  3.64   0.068  0.34     60   0.227   X X   X
480149000000             CIRRATULIDAE                  06/12/78    1     36  7.29   0.086  0.43    120   0.287   X X   X
                                                          SUBTOTAL       65 13.16   0.182  0.92    217   0.607

480149040100                CHAETOZONE SETOSA          06/12/78    1      7  1.42   0.042  0.21     23   0.140
480149040100                CHAETOZONE SETOSA          06/12/78    3      3  0.61   0.022  0.11     10   0.073
480149040100                CHAETOZONE SETOSA          06/12/78    2      1  0.20   0.004  0.02      3   0.013
                                                          SUBTOTAL       11  2.23   0.068  0.34     37   0.227

480155010100                SCALIBREGMA INFLATUM       06/12/78    2      1  0.20   0.053  0.27      3   0.177   X X X X X
480155010100                SCALIBREGMA INFLATUM       06/12/78    3     12  2.43   2.118 10.65     40   7.060   X X X X X
480155010100                SCALIBREGMA INFLATUM       06/12/78    1     11  2.23   2.321 11.67     37   7.737   X X X X X
                                                          SUBTOTAL       24  4.86   4.492 22.59     80  14.973

480158010100                CAPITELLA CAPITATA         06/12/78    2      2  0.40   0.008  0.04      7   0.027       X

480158020100                HETEROMASTUS FILIFORMIS    06/12/78    2     32  6.48   0.918  4.62    107   3.060     X X X X
480158020100                HETEROMASTUS FILIFORMIS    06/12/78    3     66 13.36   3.677 18.49    220  12.257     X X X X
480158020100                HETEROMASTUS FILIFORMIS    06/12/78    1     42  8.50   3.776 18.99    140  12.587     X X X X
                                                          SUBTOTAL      140 28.34   8.371 42.09    467  27.903

480175010100                COSSURA LONGOCIRRATA       06/12/78    1      3  0.61   0.001  0.01     10   0.003
480175010100                COSSURA LONGOCIRRATA       06/12/78    3      2  0.40   0.001  0.01      7   0.003
                                                          SUBTOTAL        5  1.01   0.002  0.01     17   0.007

490402020100                NUCULA TENUIS              06/12/78    2      1  0.20   0.002  0.01      3   0.007
490402020100                NUCULA TENUIS              06/12/78    1      1  0.20   0.001  0.01      3   0.003
                                                          SUBTOTAL        2  0.40   0.003  0.02      7   0.010

490403040000                TINDARIA SP.               06/12/78    3      4  0.81   0.007  0.04     13   0.023

490403050700                YOLDIA THRACIAFFORMIS      06/12/78    3      1  0.20   1.201  6.04      3   4.003       X

490415020000                AXINOPSIDA SP.             06/12/78    3     20  4.05   0.166  0.83     67   0.553   X X X X
490415020000                AXINOPSIDA SP.             06/12/78    2     35  7.09   0.220  1.11    117   0.733   X X X X
490415020000                AXINOPSIDA SP.             06/12/78    1     15  3.04   0.060  0.40     50   0.267   X X X X
                                                          SUBTOTAL       70 14.17   0.466  2.34    233   1.553

490424010000                MACOMA SP.                 06/12/78    2      1  0.20   0.004  0.02      3   0.013       X   X
490424010000                MACOMA SP.                 06/12/78    3      1  0.20   0.001  0.01      3   0.003       X   X
                                                          SUBTOTAL        2  0.40   0.005  0.03      7   0.017

530000000000  CRUSTACEA                                06/12/78    2      2  0.40   2.558 12.86      7   8.527       X

533100000000        AMPHIPODA                          06/12/78    3      2  0.40   0.003  0.02      7   0.010

6803090000F0             OPHIURIDAE FRAGS              06/12/78    1      1  0.20   0.001  0.01      3   0.003

                                                     STATION TOTAL      494        19.888          1647  66.293

                                                     SIMPSON INDEX 0.160046             SHANNON DIVERSITY INDEX 2.226502
 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                    03/25/79      PAGE   35
 CRUISE 761      STATION 3C                          PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                       SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE           TAXON NAME                         DATE     NO.   NO.  PCT    GRAMS   PCT     NO.    WWGT    BIT CRITERIA
3303000000F0       ANTHOZOA FRAGS                     06/12/78    5     1  0.12    0.461  0.13       2   0.922
330300000000       ANTHOZOA                           06/12/78    5     1  0.12  191.000 54.67       2 382.000        X   X
4000000000F0  RHYNCHOCOELA FRAGS.                     06/12/78    5     1  0.12    0.082  0.02       2   0.164        X   X
4000000000F0  RHYNCHOCOELA FRAGS.                     06/12/78    4     1  0.12    0.183  0.05       2   0.366        X   X
4000000000F0  RHYNCHOCOELA FRAGS.                     06/12/78    3     1  0.12    0.214  0.06       2   0.428        X   X
4000000000F0  RHYNCHOCOELA FRAGS.                     06/12/78    1     1  0.12    0.036  0.01       2   0.072        X   X
4000000000F0  RHYNCHOCOELA FRAGS.                     06/12/78    2     1  0.12    0.123  0.04       2   0.246        X   X
                                                         SUBTOTAL       5  0.61    0.638  0.18      10   1.276
400000000000  RHYNCHOCOELA                            06/12/78    4     1  0.12    0.002  0.00       2   0.004
440000000000  NEMATODA                                06/12/78    5     7  0.85    0.002  0.00      14   0.004
4801000000F0       POLYCHAETA FRAG.                   06/12/78    5     1  0.12    0.027  0.01       2   0.054    X
4801000000F0       POLYCHAETA FRAG.                   06/12/78    4     1  0.12    0.152  0.04       2   0.304    X
4801000000F0       POLYCHAETA FRAG.                   06/12/78    3     1  0.12    0.038  0.01       2   0.076    X
4801000000F0       POLYCHAETA FRAG.                   06/12/78    2     1  0.12    0.086  0.02       2   0.172    X
4801000000F0       POLYCHAETA FRAG.                   06/12/78    1     1  0.12    0.060  0.02       2   0.120    X
                                                         SUBTOTAL       5  0.61    0.363  0.10      10   0.726
480101000000            POLYNOIDAE                    06/12/78    1     1  0.12    0.002  0.00       2   0.004
480101000000            POLYNOIDAE                    06/12/78    2     5  0.61    0.082  0.02      10   0.164
480101000000            POLYNOIDAE                    06/12/78    3     4  0.49    0.017  0.00       8   0.034
480101000000            POLYNOIDAE                    06/12/78    4     2  0.24    0.020  0.01       4   0.040
480101000000            POLYNOIDAE                    06/12/78    5     3  0.37    0.051  0.01       6   0.102
                                                         SUBTOTAL      15  1.83    0.172  0.05      30   0.344
480105010100                 PHLOE MINUTA             06/12/78    4     1  0.12    0.004  0.00       2   0.008      X
480120010200                 GYPTIS BREVIPALPA        06/12/78    1     1  0.12    0.003  0.00       2   0.006
480124010400                 NEPHTYS CORNUTA          06/12/78    1     6  0.73    0.020  0.01      12   0.040    X X X X X
480124010400                 NEPHTYS CORNUTA          06/12/78    2    23  2.80    0.064  0.02      46   0.128    X X X X X
480124010400                 NEPHTYS CORNUTA          06/12/78    4    29  3.54    0.091  0.03      58   0.182    X X X X X
480124010400                 NEPHTYS CORNUTA          06/12/78    3     5  0.61    0.018  0.01      10   0.036    X X X X X
480124010400                 NEPHTYS CORNUTA          06/12/78    5    27  3.29    0.084  0.02      54   0.168    X X X X X
                                                         SUBTOTAL      90 10.98    0.277  0.08     180   0.554
480124010500                 NEPHTYS PUNCTATA         06/12/78    1     1  0.12    9.358  2.68       2  18.716
480126000000            GLYCERIDAE                    06/12/78    5     1  0.12    0.002  0.00       2   0.004
480126000000            GLYCERIDAE                    06/12/78    3     2  0.24    0.016  0.00       4   0.032
                                                         SUBTOTAL       3  0.37    0.018  0.01       6   0.036
480127010100                 GLYCINDE PICTA           06/12/78    2     2  0.24    0.009  0.00       4   0.018    X
480130011900                 LUMBRINERIS LUTI         06/12/78    2     1  0.12    0.009  0.00       2   0.018    X X   X
480130011900                 LUMBRINERIS LUTI         06/12/78    1     1  0.12    0.007  0.00       2   0.014    X X   X
480130011900                 LUMBRINERIS LUTI         06/12/78    4     1  0.12    0.013  0.00       2   0.026    X X   X
480130011900                 LUMBRINERIS LUTI         06/12/78    5     2  0.24    0.038  0.01       4   0.076    X X   X
                                                         SUBTOTAL       5  0.61    0.067  0.02      10   0.134
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 3C

03/25/79 PAGE 36

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
480142000000	SPIONIDAE	06/12/78	1	1	0.12	0.012	0.00	2	0.024	
480142020000	LAONICE SP.	06/12/78	2	1	0.12	0.002	0.00	2	0.004	
480142050100	PRIONOSPIO MALMGRENI	06/12/78	2	9	1.10	0.040	0.01	18	0.080	X X X
480142050100	PRIONOSPIO MALMGRENI	06/12/78	1	1	0.12	0.021	0.01	2	0.042	X X X
480142050100	PRIONOSPIO MALMGRENI	06/12/78	5	10	1.22	0.064	0.02	20	0.128	X X X
480142050100	PRIONOSPIO MALMGRENI	06/12/78	4	10	1.22	0.084	0.02	20	0.168	X X X
480142050100	PRIONOSPIO MALMGRENI	06/12/78	3	2	0.24	0.003	0.00	4	0.006	X X X
		SUBTOTAL		32	3.90	0.212	0.06	64	0.424	
480142050200	PRIONOSPIO CIRRIFERA	06/12/78	4	12	1.46	0.010	0.00	24	0.020	
480142050200	PRIONOSPIO CIRRIFERA	06/12/78	1	1	0.12	0.001	0.00	2	0.002	
		SUBTOTAL		13	1.59	0.011	0.00	26	0.022	
480142100100	SPIOPHANES BOMBYX	06/12/78	1	1	0.12	0.001	0.00	2	0.002	
480142100200	SPIOPHANES KROYERI	06/12/78	2	1	0.12	0.043	0.01	2	0.086	
480142100200	SPIOPHANES KROYERI	06/12/78	5	2	0.24	0.007	0.00	4	0.014	
		SUBTOTAL		3	0.37	0.050	0.01	6	0.100	
480149000000	CIRRATULIDAE	06/12/78	5	25	3.05	0.129	0.04	50	0.258	X X X
480149000000	CIRRATULIDAE	06/12/78	2	35	4.27	0.200	0.06	70	0.400	X X X
480149000000	CIRRATULIDAE	06/12/78	4	31	3.78	0.128	0.04	62	0.256	X X X
480149000000	CIRRATULIDAE	06/12/78	3	12	1.46	0.078	0.02	24	0.156	X X X
480149000000	CIRRATULIDAE	06/12/78	1	22	2.68	0.096	0.03	44	0.192	X X X
		SUBTOTAL		125	15.24	0.631	0.18	250	1.262	
480149040100	CHAETOZONE SETOSA	06/12/78	1	3	0.37	0.041	0.01	6	0.082	
480149040100	CHAETOZONE SETOSA	06/12/78	5	3	0.37	0.030	0.01	6	0.060	
480149040100	CHAETOZONE SETOSA	06/12/78	4	7	0.85	0.047	0.01	14	0.094	
		SUBTOTAL		13	1.59	0.118	0.03	26	0.236	
480155010100	SCALIBREGMA INFLATUM	06/12/78	4	19	2.32	2.863	0.82	38	5.726	X X X X X
490155010100	SCALIBREGMA INFLATUM	06/12/78	5	19	2.32	1.802	0.52	38	3.604	X X X X X
480155010100	SCALIBREGMA INFLATUM	06/12/78	3	37	4.51	4.280	1.23	74	8.560	X X X X X
480155010100	SCALIBREGMA INFLATUM	06/12/78	2	24	2.93	4.068	1.16	48	8.136	X X X X X
480155010100	SCALIBREGMA INFLATUM	06/12/78	1	21	2.56	1.881	0.54	42	3.762	X X X X X
		SUBTOTAL		120	14.63	14.894	4.26	240	29.788	
480156010100	AMMOTRYPANE AULOGASTER	06/12/78	2	2	0.24	0.141	0.04	4	0.282	X
480156010100	AMMOTRYPANE AULOGASTER	06/12/78	5	1	0.12	0.055	0.02	2	0.110	X
		SUBTOTAL		3	0.37	0.196	0.06	6	0.392	
480158020100	HETEROMASTUS FILIFORMIS	06/12/78	5	81	9.88	2.480	0.71	162	4.960	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/12/78	4	49	5.98	0.320	0.09	98	0.640	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/12/78	2	56	6.83	2.475	0.71	112	4.950	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/12/78	3	96	11.71	5.436	1.56	192	10.872	X X X X
480158020100	HETEROMASTUS FILIFORMIS	06/12/78	1	25	3.05	1.310	0.37	50	2.620	X X X X
		SUBTOTAL		307	37.44	12.021	3.44	614	24.042	

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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
CRUISE 261       STATION 3C                                                                      03/25/79        PAGE   37
                                                       PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
TAXON CODE              TAXON NAME                       SAMPLE   SAMP      COUNT       WET WEIGHT      PER SQ METER
                                                          DATE     NO.    NO.   PCT    GRAMS    PCT      NO.    WWGT     BIT CRITERIA
480175010100                  COSSURA LONGOCIRRATA      06/12/78    4       2  0.24    0.001   0.00       4    0.002

490403000000           NUCULANIDAE                      06/12/78    4       2  0.24    0.005   0.00       4    0.010
490403000000           NUCULANIDAE                      06/12/78    3       1  0.12    0.001   0.00       2    0.002
490403000000           NUCULANIDAE                      06/12/78    2       4  0.49    0.009   0.00       8    0.018
490403000000           NUCULANIDAE                      06/12/78    1       3  0.37    0.005   0.00       6    0.010
                                                           SUBTOTAL        10  1.22    0.020   0.01      20    0.040

490403020300                  NUCULANA FOSSA            06/12/78    4       1  0.12    0.016   0.00       2    0.032         X   X

490403050700                  YOLDIA THRACIAFFORMIS     06/12/78    4       1  0.12   19.485   5.58       2   38.970         X
490403050700                  YOLDIA THRACIAFFORMIS     06/12/78    5       1  0.12   19.791   5.67       2   39.582         X
490403050700                  YOLDIA THRACIAFFORMIS     06/12/78    2       1  0.12    8.042   2.30       2   16.084         X
                                                           SUBTOTAL         3  0.37   47.318  13.55       6   94.636

490415020000                  AXINOPSIDA SP.            06/12/78    2       8  0.98    0.070   0.02      16    0.140    X X X X
490415020000                  AXINOPSIDA SP.            06/12/78    3       7  0.85    0.107   0.03      14    0.214    X X X X
490415020000                  AXINOPSIDA SP.            06/12/78    5       1  0.12    0.001   0.00       2    0.002    X X X X
490415020000                  AXINOPSIDA SP.            06/12/78    4       8  0.98    0.073   0.02      16    0.146    X X X X
490415020000                  AXINOPSIDA SP.            06/12/78    1       5  0.61    0.022   0.01      10    0.044    X X X X
                                                           SUBTOTAL        29  3.54    0.273   0.08      58    0.546

490423010000                  SPISULA SP.               06/12/78    4       1  0.12    0.001   0.00       2    0.002         X   X

490424010100                  MACOMA CALCAREA           06/12/78    1       1  0.12    3.701   1.06       2    7.402         X   X

490424010300                  MACOMA BROTA              06/12/78    3       1  0.12   41.655  11.92       2   83.310         X   X
490424010300                  MACOMA BROTA              06/12/78    2       1  0.12   24.846   7.11       2   49.692         X   X
                                                           SUBTOTAL         2  0.24   66.501  19.04       4  133.002

490424011300                  MACOMA CARLOTTENSIS       06/12/78    2       1  0.12    0.558   0.16       2    1.116

490500000000         GASTROPODA                         06/12/78    4       2  0.24    0.002   0.00       4    0.004

533100000000         AMPHIPODA                          06/12/78    4       6  0.73    0.011   0.00      12    0.022
533100000000         AMPHIPODA                          06/12/78    5       1  0.12    0.002   0.00       2    0.004
                                                           SUBTOTAL         7  0.85    0.013   0.00      14    0.026

533300000000         DECAPODA                           06/12/78    4       1  0.12    0.288   0.08       2    0.576

9999999999F0     UNIDENTIFIED FRAGS.                    06/12/78    5       1  0.12    0.123   0.04       2    0.246

999999999900     UNIDENTIFIED                           06/12/78    1       2  0.24    0.002   0.00       4    0.004
                                                     STATION TOTAL        820         349.339           1640  698.678
                                                     SIMPSON INDEX 0.200015              SHANNON DIVERSITY INDEX 2.134240
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 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                          03/25/79      PAGE   38
CRUISE 261      STATION 3E                              PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                          SAMPLE  SAMP     COUNT     WET WEIGHT   PER SQ METER
TAXON CODE            TAXON NAME                           DATE    NO.   NO.  PCT   GRAMS  PCT    NO.   WWGT   BIT CRITERIA
999900000000 NO FAUNA COLLECTED IN THIS GRAB             06/11/78    1     0******  0.    ******    0   0.       X X X X
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                                                                                         03/25/79        PAGE   39
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978          PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 261        STATION 3F                                                 COUNT     WET WEIGHT    PER SQ METER
                                                     SAMPLE      SAMP                                                BIT CRITERIA
TAXON CODE        TAXON NAME                          DATE        NO.     NO.   PCT    GRAMS   PCT    NO.   WWGT

310431000000      FORAMINIFERA                       06/11/78      2        1   0.04   0.001  0.00      2   0.002   X  X
400000000000      RHYNCHOCOELA                       06/11/78      5        2   0.09   0.041  0.04      4   0.092
4800000000F0      ANNELIDA FRAGS                     06/11/78      2        1   0.04   0.818  0.83      2   1.636
4800000000F0      ANNELIDA FRAGS                     06/11/78      1        1   0.04   0.622  0.63      2   1.244
                                                        SUBTOTAL            2   0.09   1.440  1.45      4   2.880
4801000000F0      POLYCHAETA FRAG.                   06/11/78      5        1   0.04   0.183  0.18      2   0.366   X
4801000000F0      POLYCHAETA FRAG.                   06/11/78      4        1   0.04   0.124  0.13      2   0.248   X
                                                        SUBTOTAL            2   0.09   0.307  0.31      4   0.614
480101000000      POLYNOIDAE                         06/11/78      1        3   0.13   0.021  0.02      6   0.042
480101000000      POLYNOIDAE                         06/11/78      2        3   0.13   0.019  0.02      6   0.038
480101000000      POLYNOIDAE                         06/11/78      3        7   0.31   0.020  0.02     14   0.040
                                                        SUBTOTAL           13   0.57   0.060  0.06     26   0.120
480101020000      NEMIDIA SP.                        06/11/78      4        1   0.04   0.005  0.01      2   0.010
480120010200      GYPTIS BREVIPALPA                  06/11/78      5        2   0.09   0.003  0.00      4   0.006
480124010400      NEPHTYS CORNUTA                    06/11/78      4        2   0.09   0.004  0.00      4   0.008   X  X  X  X  X
480124010400      NEPHTYS CORNUTA                    06/11/78      3        1   0.04   0.001  0.00      2   0.002   X  X  X  X  X
480124010400      NEPHTYS CORNUTA                    06/11/78      2        1   0.04   0.001  0.00      2   0.002   X  X  X  X  X
                                                        SUBTOTAL            4   0.17   0.006  0.01      8   0.012
480124010500      NEPHTYS PUNCTATA                   06/11/78      1        1   0.04   2.123  2.14      2   4.246
480124010500      NEPHTYS PUNCTATA                   06/11/78      4        1   0.04   0.733  0.74      2   1.466
                                                        SUBTOTAL            2   0.09   2.856  2.88      4   5.712
480126010100      GLYCERA CAPITATA                   06/11/78      4        2   0.09   0.065  0.07      4   0.130
480126010100      GLYCERA CAPITATA                   06/11/78      2        1   0.04   0.066  0.07      2   0.132
                                                        SUBTOTAL            3   0.13   0.131  0.13      6   0.262
480127010100      GLYCINDE PICTA                     06/11/78      2       16   0.70   0.236  0.24     32   0.472   X
480127010100      GLYCINDE PICTA                     06/11/78      1        7   0.31   0.214  0.22     14   0.428   X
480127010100      GLYCINDE PICTA                     06/11/78      3        4   0.17   0.110  0.11      8   0.220   X
480127010100      GLYCINDE PICTA                     06/11/78      4        4   0.17   0.072  0.07      8   0.144   X
480127010100      GLYCINDE PICTA                     06/11/78      5        8   0.35   0.095  0.10     16   0.190   X
                                                        SUBTOTAL           39   1.70   0.727  0.73     78   1.454
480127010300      GLYCINDE ARMIGFRA                  06/11/78      5        1   0.04   0.002  0.00      2   0.004
4801300100F0      LUMBRINERIS SP. FRAGS.             06/11/78      5        1   0.04   0.292  0.29      2   0.584
480130011900      LUMBRINERIS LUTI                   06/11/78      5       71   3.10   0.453  0.46    142   0.906   X  X     X
480130011900      LUMBRINERIS LUTI                   06/11/78      4       22   0.96   0.307  0.31     44   0.614   X  X     X
480130011900      LUMBRINERIS LUTI                   06/11/78      3       21   0.92   0.142  0.14     42   0.284   X  X     X
480130011900      LUMBRINERIS LUTI                   06/11/78      1       72   3.15   0.554  0.56    144   1.108   X  X     X
480130011900      LUMBRINERIS LUTI                   06/11/78      2       62   2.71   0.595  0.60    124   1.190   X  X     X
                                                        SUBTOTAL          248  10.83   2.051  2.07    496   4.102
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 3F

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	2	5	0.22	0.304	0.31	10	0.608	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	1	4	0.17	0.122	0.12	8	0.244	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	3	1	0.04	0.021	0.02	2	0.042	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	5	7	0.31	0.325	0.33	14	0.650	
		SUBTOTAL		17	0.74	0.772	0.78	34	1.544	
480139030000	SCOLOPLOS FULIGINOSA	06/11/78	1	1	0.04	0.017	0.02	2	0.034	
480139030000	SCOLOPLOS FULIGINOSA	06/11/78	2	2	0.09	0.011	0.01	4	0.022	
		SUBTOTAL		3	0.13	0.028	0.03	6	0.056	
4801420000F0	SPIONIDAE FRAGS	06/11/78	5	1	0.04	0.590	0.60	2	1.180	
4801420000F0	SPIONIDAE FRAGS	06/11/78	4	1	0.04	0.109	0.11	2	0.218	
		SUBTOTAL		2	0.09	0.699	0.71	4	1.398	
480142040000	POLYDORA SP.	06/11/78	1	2	0.09	0.027	0.03	4	0.054	
480142050100	PRIONOSPIO MALMGRENI	06/11/78	1	28	1.22	0.126	0.13	56	0.252	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	2	21	0.92	0.158	0.16	42	0.316	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	3	16	0.70	0.159	0.16	32	0.318	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	4	12	0.52	0.078	0.08	24	0.156	X X X
480142050100	PRIONOSPIO MALMGRENI	06/11/78	5	34	1.49	0.189	0.19	68	0.378	X X X
		SUBTOTAL		111	4.85	0.710	0.72	222	1.420	
480142070100	SPIO FILICORNIS	06/11/78	5	7	0.31	0.046	0.05	14	0.092	
480142100200	SPIOPHANES KROYERI	06/11/78	3	8	0.35	0.344	0.35	16	0.688	
480142100200	SPIOPHANES KROYERI	06/11/78	2	64	2.80	2.401	2.42	128	4.802	
480142100200	SPIOPHANES KROYERI	06/11/78	1	36	1.57	0.855	0.86	72	1.710	
		SUBTOTAL		108	4.72	3.600	3.63	216	7.200	
480142100300	SPIOPHANES CIRRATA	06/11/78	5	27	1.18	0.695	0.70	54	1.390	
480142100300	SPIOPHANES CIRRATA	06/11/78	4	15	0.66	0.174	0.18	30	0.348	
		SUBTOTAL		42	1.83	0.869	0.88	84	1.738	
480143010200	MAGELONA PACIFICA	06/11/78	4	7	0.31	0.039	0.04	14	0.078	
480143010200	MAGELONA PACIFICA	06/11/78	5	11	0.48	0.120	0.12	22	0.240	
480143010200	MAGELONA PACIFICA	06/11/78	1	2	0.09	0.014	0.01	4	0.028	
480143010200	MAGELONA PACIFICA	06/11/78	2	8	0.35	0.085	0.09	16	0.170	
480143010200	MAGELONA PACIFICA	06/11/78	3	1	0.04	0.011	0.01	2	0.022	
		SUBTOTAL		29	1.27	0.269	0.27	58	0.538	
480149000000	CIRRATULIDAE	06/11/78	5	15	0.66	0.129	0.13	30	0.258	X X X
480149030000	THARYX SP.	06/11/78	4	9	0.39	0.027	0.03	18	0.054	X
480149030000	THARYX SP.	06/11/78	3	21	0.92	0.120	0.12	42	0.240	X
480149030000	THARYX SP.	06/11/78	2	16	0.70	0.080	0.08	32	0.160	X
480149030000	THARYX SP.	06/11/78	1	23	1.00	0.160	0.16	46	0.320	X
		SUBTOTAL		69	3.01	0.387	0.39	138	0.774	

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                                                                                                   03/25/79        PAGE   41
  DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                            PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
 CRUISE 261       STATION 3F                                      SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
                                                                   DATE     NO.   NO.  PCT    GRAMS   PCT    NO.    WWGT    BIT CRITERIA
 TAXON CODE              TAXON NAME
                                                                 06/11/78    1    10  0.44    0.583  0.59     20    1.166   X X X X X
 480155010100                  SCALIBREGMA INFLATUM              06/11/78    2     9  0.39    0.317  0.32     18    0.634   X X X X X
 480155010100                  SCALIBREGMA INFLATUM              06/11/78    3    11  0.48    1.284  1.30     22    2.568   X X X X X
 480155010100                  SCALIBREGMA INFLATUM              06/11/78    4     4  0.17    0.116  0.12      8    0.232   X X X X X
 480155010100                  SCALIBREGMA INFLATUM              06/11/78    5    17  0.74    0.684  0.69     34    1.368   X X X X X
 480155010100                  SCALIBREGMA INFLATUM                 SUBTOTAL      51  2.23    2.984  3.01    102    5.968

                                                                 06/11/78    5     1  0.04    0.067  0.07      2    0.134   X
 480156010100                  AMMOTRYPANE AULOGASTER            06/11/78    3     1  0.04    0.067  0.07      2    0.134   X
 480156010100                  AMMOTRYPANE AULOGASTER               SUBTOTAL       2  0.09    0.134  0.14      4    0.268

                                                                 06/11/78    4     1  0.04    0.106  0.11      2    0.212
 4801580000F0              CAPITELLIDAE FRAGS
                                                                 06/11/78    5     1  0.04    0.003  0.00      2    0.006
 480158000000              CAPITELLIDAE
                                                                 06/11/78    3    22  0.96    0.420  0.42     44    0.840        X
 480158010100                  CAPITELLA CAPITATA                06/11/78    2    10  0.44    0.124  0.13     20    0.248        X
 480158010100                  CAPITELLA CAPITATA                06/11/78    1     5  0.22    0.118  0.12     10    0.236        X
 480158010100                  CAPITELLA CAPITATA                   SUBTOTAL      37  1.62    0.662  0.67     74    1.324

                                                                 06/11/78    2     4  0.17    0.013  0.01      8    0.026
 480158020000                  HETEROMASTUS SP. FRAGS            06/11/78    3     3  0.13    0.004  0.00      6    0.008
 480158020000                  HETEROMASTUS SP. FRAGS            06/11/78    4     5  0.22    0.129  0.13     10    0.258
 480158020000                  HETEROMASTUS SP. FRAGS               SUBTOTAL      12  0.52    0.146  0.15     24    0.292

                                                                 06/11/78    4     9  0.39    0.198  0.20     18    0.396      X X X X
 480158020100                  HETEROMASTUS FILIFORMIS           06/11/78    5    21  0.92    0.171  0.17     42    0.342      X X X X
 480158020100                  HETEROMASTUS FILIFORMIS           06/11/78    3     9  0.39    0.307  0.31     18    0.614      X X X X
 480158020100                  HETEROMASTUS FILIFORMIS              SUBTOTAL      39  1.70    0.676  0.68     78    1.352

                                                                 06/11/78    1     3  0.13    0.006  0.01      6    0.012
 480158030000                  NOTOMASTUS SP.                    06/11/78    4     2  0.09    0.009  0.01      4    0.018
 480158030000                  NOTOMASTUS SP.                       SUBTOTAL       5  0.22    0.015  0.02     10    0.030

                                                                 06/11/78    5     5  0.22    0.041  0.04     10    0.082
 480158030600                  NOTOMASTUS LAERIATUS
                                                                 06/11/78    5     1  0.04    1.143  1.15      2    2.286
 4801610000F0              MALDANIDAE FRAGS.
                                                                 06/11/78    5     1  0.04    0.657  0.66      2    1.314
 480161080100                  AXIOTHELLA CATENATA               06/11/78    1     9  0.39    2.864  2.89     18    5.728
 480161080100                  AXIOTHELLA CATENATA               06/11/78    2    15  0.66    2.605  2.63     30    5.210
 480161080100                  AXIOTHELLA CATENATA                  SUBTOTAL      25  1.09    6.126  6.19     50   12.252

                                                                 06/11/78    4     7  0.31    0.347  0.35     14    0.694
 480161090200                  PRAXILLELLA PRAETERMISSA
                                                                 06/11/78    2     1  0.04    0.005  0.01      2    0.010
 480165000000              AMPHARETIDAE
                                                                 06/11/78    2     2  0.09    0.007  0.01      4    0.014
 480165020100                  AMPHARETE ARCTICA                 06/11/78    3     4  0.17    0.008  0.01      8    0.016
 480165020100                  AMPHARETE ARCTICA                    SUBTOTAL       6  0.26    0.015  0.02     12    0.030
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
CRUISE 261        STATION 3F                                PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

                                                            SAMPLE    SAMP      COUNT      WET WEIGHT     PER SQ METER
TAXON CODE          TAXON NAME                               DATE      NO.    NO.  PCT    GRAMS   PCT     NO.   WHGT    BIT CRITERIA

480168010300              CHONE CINCTA                      06/11/78   5      17  0.74    0.490  0.49     34   0.980
480158010300              CHONE CINCTA                      06/11/78   4       1  0.04    0.023  0.02      2   0.046
480168010300              CHONE CINCTA                      06/11/78   2      20  0.87    0.531  0.54     40   1.062
480158010300              CHONE CINCTA                      06/11/78   3       2  0.09    0.013  0.01      4   0.026
480168010300              CHONE CINCTA                      06/11/78   1      13  0.57    0.410  0.41     26   0.820
                                                               SUBTOTAL       53  2.32    1.467  1.48    106   2.934

4904000000F0        PELECYPODA FRAGS.                       06/11/78   3       1  0.04    0.340  0.34      2   0.680

490402020100              NUCULA TENUIS                     06/11/78   4       1  0.04    0.001  0.00      2   0.002
490402020100              NUCULA TENUIS                     06/11/78   2       3  0.13    0.006  0.01      6   0.012
                                                               SUBTOTAL        4  0.17    0.007  0.01      8   0.014

490403000000           NUCULANIDAE                          06/11/78   2       1  0.04    0.001  0.00      2   0.002
490403000000           NUCULANIDAE                          06/11/78   1       4  0.17    0.008  0.01      8   0.016
490403000000           NUCULANIDAE                          06/11/78   3       4  0.17    0.003  0.00      8   0.006
490403000000           NUCULANIDAE                          06/11/78   5       2  0.09    0.004  0.00      4   0.008
                                                               SUBTOTAL       11  0.48    0.016  0.02     22   0.032

490403020300              NUCULANA FOSSA                    06/11/78   5      13  0.57    1.128  1.14     26   2.256           X   X
490403020300              NUCULANA FOSSA                    06/11/78   3       1  0.04    0.048  0.05      2   0.096           X   X
490403020300              NUCULANA FOSSA                    06/11/78   4       1  0.04    0.087  0.09      2   0.174           X   X
490403020300              NUCULANA FOSSA                    06/11/78   1       3  0.13    0.094  0.09      6   0.188           X   X
490403020300              NUCULANA FOSSA                    06/11/78   2       8  0.35    1.012  1.02     16   2.024           X   X
                                                               SUBTOTAL       26  1.14    2.369  2.39     52   4.738

490403040000              TINDARIA SP.                      06/11/78   4       4  0.17    0.008  0.01      8   0.016

490415020000              AXINOPSIDA SP.                    06/11/78   4     185  8.08    0.877  0.89    370   1.754   X X X X
490415020000              AXINOPSIDA SP.                    06/11/78   3     137  5.99    0.819  0.83    274   1.638   X X X X
490415020000              AXINOPSIDA SP.                    06/11/78   5     350 15.29    1.488  1.50    700   2.976   X X X X
490415020000              AXINOPSIDA SP.                    06/11/78   2     264 11.53    1.013  1.02    528   2.026   X X X X
490415020000              AXINOPSIDA SP.                    06/11/78   1     313 13.67    1.330  1.34    626   2.660   X X X X
                                                               SUBTOTAL     1249 54.57    5.527  5.58   2498  11.054

490424010100              MACOMA CALCAREA                   06/11/78   2       3  0.13    1.998  2.02      6   3.996           X   X
490424010100              MACOMA CALCAREA                   06/11/78   3       3  0.13    5.315  5.37      6  10.630           X   X
490424010100              MACOMA CALCAREA                   06/11/78   4       2  0.09   14.352 14.49      4  28.704           X   X
                                                               SUBTOTAL        8  0.35   21.665 21.87     16  43.330

490424010300              MACOMA BROTA                      06/11/78   3       2  0.09   39.726 40.11      4  79.452           X   X

4905000000F0        GASTROPODA FRAGS                        06/11/78   2       1  0.04    0.001  0.00      2   0.002

531200000000        CYCLOPOIDA                              06/11/78   2       1  0.04    0.001  0.00      2   0.002

590101010100              GOLFINGIA MARGARITACEA            06/11/78   2       6  0.26    0.028  0.03     12   0.056
590101010100              GOLFINGIA MARGARITACEA            06/11/78   1       2  0.09    0.020  0.02      4   0.040
590101010100              GOLFINGIA MARGARITACEA            06/11/78   5       2  0.09    0.005  0.01      4   0.010
                                                               SUBTOTAL       10  0.44    0.053  0.05     20   0.106

                                                            STATION TOTAL   2289          99.041          4578 198.082

                                                            SIMPSON INDEX 0.317553          SHANNON DIVERSITY INDEX 1.990431
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978              PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

CRUISE 261      STATION 3G                               SAMPLE    SAMP     COUNT      WET WEIGHT    PER SQ METER    BIT CRITERIA
                                                          DATE      NO.   NO.  PCT    GRAMS   PCT     NO.   WWGT
TAXON CODE            TAXON NAME

4800000000F0  ANNELIDA FRAGS                             06/11/78    3      1  0.28   0.834  2.05       2  1.668
4801000000F0      POLYCHAETA FRAG.                       06/11/78    4      1  0.28   0.001  0.00       2  0.002   X
480100000000      POLYCHAETA                             06/11/78    5      1  0.28   0.003  0.01       2  0.006
480124010400            NEPHTYS CORNUTA                  06/11/78    5      1  0.28   0.002  0.00       2  0.004   X X X X X
480124010400            NEPHTYS CORNUTA                  06/11/78    1      5  1.40   0.007  0.02      10  0.014   X X X X X
480124010400            NEPHTYS CORNUTA                  06/11/78    2      1  0.28   0.002  0.00       2  0.004   X X X X X
                                                           SUBTOTAL         7  1.97   0.011  0.03      14  0.022
480126000000          GLYCERIDAE                         06/11/78    3      1  0.28   0.003  0.01       2  0.006
480127010100            GLYCINDE PICTA                   06/11/78    3      2  0.56   0.031  0.08       4  0.062   X
480127010100            GLYCINDE PICTA                   06/11/78    5      1  0.28   0.034  0.08       2  0.068   X
                                                           SUBTOTAL         3  0.84   0.065  0.16       6  0.130
480130011900            LUMBRINERIS LUTI                 06/11/78    5      1  0.28   0.061  0.15       2  0.122   X X   X
480130011900            LUMBRINERIS LUTI                 06/11/78    3     45 12.64   0.990  2.44      90  1.980   X X   X
                                                           SUBTOTAL        46 12.92   1.051  2.59      92  2.102
480139010200            HAPLOSCOLOPLOS ELONGATUS         06/11/78    3     11  3.09   0.894  2.20      22  1.788
480139010200            HAPLOSCOLOPLOS ELONGATUS         06/11/78    5      4  1.12   0.382  0.94       8  0.764
                                                           SUBTOTAL        15  4.21   1.276  3.14      30  2.552
480142050100            PRIONOSPIO MALMGRENI             06/11/78    5      9  2.53   0.020  0.05      18  0.040   X X   X
480142050100            PRIONOSPIO MALMGRENI             06/11/78    3     41 11.52   0.186  0.46      82  0.372   X X   X
490142050100            PRIONOSPIO MALMGRENI             06/11/78    1      3  0.84   0.005  0.01       6  0.010   X X   X
                                                           SUBTOTAL        53 14.89   0.211  0.52     106  0.422
480142100100            SPIOPHANES BOMBYX                06/11/78    3      1  0.28   0.010  0.02       2  0.020
480143010200            MAGELONA PACIFICA                06/11/78    3      7  1.97   0.078  0.19      14  0.156
480149030000            THARYX SP.                       06/11/78    3      9  2.53   0.054  0.13      18  0.108     X
480149030000            THARYX SP.                       06/11/78    5     17  4.78   0.112  0.28      34  0.224     X
                                                           SUBTOTAL        26  7.30   0.166  0.41      52  0.332
4801580000F0          CAPITELLIDAE FRAGS                 06/11/78    2      1  0.28   0.133  0.33       2  0.266
4801580000F0          CAPITELLIDAE FRAGS                 06/11/78    1      1  0.28   0.116  0.29       2  0.232
                                                           SUBTOTAL         2  0.56   0.249  0.61       4  0.498
480158000000          CAPITELLIDAE                       06/11/78    3      1  0.28   0.001  0.00       2  0.002
480158020000            HETEROMASTUS SP. FRAGS           06/11/78    4      1  0.28   0.073  0.18       2  0.146
480158020000            HETEROMASTUS SP. FRAGS           06/11/78    5      2  0.56   0.053  0.13       4  0.106
                                                           SUBTOTAL         3  0.84   0.126  0.31       6  0.252
4904000000F0      PELECYPODA FRAGS.                      06/11/78    3      1  0.28   0.005  0.01       2  0.010
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                                                                                       03/25/79       PAGE   44
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978           PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 261     STATION 3G                              SAMPLE   SAMP       COUNT      WET WEIGHT    PER SQ METER    BIT CRITERIA
TAXON CODE          TAXON NAME                          DATE     NO.    NO.  PCT     GRAMS   PCT      NO.   WHGT
490403020000              NUCULANA SP.               06/11/78     3      1   0.28    0.595   1.47      2    1.190
490403060000              YOLDIELLA SP.              06/11/78     5      1   0.28    0.003   0.01      2    0.006
490414000000          LUCINIDAE                      06/11/78     3      6   1.69    0.009   0.02     12    0.018
490415020000                  AXINOPSIDA SP.         06/11/78     3     83  23.31    0.124   0.31    166    0.248     X X X X
490415020000                  AXINOPSIDA SP.         06/11/78     4      5   1.40    0.005   0.01     10    0.010     X X X X
490415020000                  AXINOPSIDA SP.         06/11/78     5     25   7.02    0.093   0.23     50    0.186     X X X X
490415020000                  AXINOPSIDA SP.         06/11/78     2     26   7.30    0.054   0.13     52    0.108     X X X X
                                                        SUBTOTAL           139  39.04    0.276   0.68    278    0.552
490415030100                  THYASIRA FLEXUOSA      06/11/78     5      1   0.28    0.043   0.11      2    0.086
490415030100                  THYASIRA FLEXUOSA      06/11/78     3      6   1.69    0.220   0.54     12    0.440
                                                        SUBTOTAL             7   1.97    0.263   0.65     14    0.526
490417000000           KELLIIDAE                     06/11/78     3      7   1.97    0.009   0.02     14    0.018         X   X
490424010100                MACOMA CALCAREA          06/11/78     3      1   0.28    0.356   0.88      2    0.712         X   X
490424010300                MACOMA BROTA             06/11/78     1      1   0.28   34.902  85.97      2   69.804
490428000000           MYIDAE                        06/11/78     3     13   3.65    0.027   0.07     26    0.054
490428020000                MYA SP.                  06/11/78     5      7   1.97    0.011   0.03     14    0.022
490428020000                MYA SP.                  06/11/78     2      2   0.56    0.005   0.01      4    0.010
                                                        SUBTOTAL             9   2.53    0.016   0.04     18    0.032
490506040000                SOLARIELLA SP.           06/11/78     3      1   0.28    0.051   0.13      2    0.102
490511010000                SOLARIELLA SP.           06/11/78     4      1   0.28    0.002   0.00      2    0.004
                                                     STATION TOTAL         356              40.599           712   81.198
                                                     SIMPSON INDEX 0.200253             SHANNON DIVERSITY INDEX 2.155550
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                    03/25/79       PAGE   45
CRUISE 761       STATION 3H                                   PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                                 SAMPLE   SAMP      COUNT      WET WEIGHT    PER SQ METER
TAXON CODE              TAXON NAME                                DATE     NO.    NO.   PCT    GRAMS   PCT     NO.   WWGT    BIT CRITERIA
4800000000F0  ANNELIDA FRAGS                                    06/11/78    5      1  1.52    0.014  0.05      3   0.047
480124010400                NEPHTYS CORNUTA                     06/11/78    5     43 65.15    0.069  0.26    143   0.230    X X X X X
480124010400                NEPHTYS CORNUTA                     06/11/78    2      1  1.52    0.005  0.02      3   0.017    X X X X X
                                                                   SUBTOTAL       44 66.67    0.074  0.27    147   0.247
480142050100                PRIONOSPIO MALMGRENI                06/11/78    5      3  4.55    0.004  0.01     10   0.013    X X   X
480149030000                THARYX SP.                          06/11/78    5      8 12.12    0.009  0.03     27   0.030      X
480158000000            CAPITELLIDAE                            06/11/78    5      4  6.06    0.733  2.72     13   2.443
4904000000F0      PELECYPODA FRAGS.                             06/11/78    5      1  1.52    0.002  0.01      3   0.007
490415020000                AXINOPSIDA SP.                      06/11/78    5      2  3.03    0.006  0.02      7   0.020    X X X X
490416010000                DIPLODONTA SP.                      06/11/78    5      1  1.52    0.001  0.00      3   0.003
490424010300                MACOMA BROTA                        06/11/78    5      1  1.52   24.372 90.53      3  81.240        X   X
533304010600                PANDALUS HYPSINOTUS                 06/11/78    5      1  1.52    1.705  6.33      3   5.683
999900000000 NO FAUNA COLLECTED IN THIS GRAB                    06/11/78    1      0  0.      0.     0.        0   0.          X X X X
                                                              STATION TOTAL       66         26.920          220  89.733
                                                              SIMPSON INDEX 0.458741        SHANNON DIVERSITY INDEX 1.259849
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                                   03/25/79      PAGE  46
CRUISE 261      STATION 31                                    PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                                SAMPLE   SAMP      COUNT      WET WEIGHT    PER SQ METER
TAXON CODE          TAXON NAME                                   DATE    NO.    NO.  PCT    GRAMS   PCT     NO.    WWGT    BIT CRITERIA
4000000000F0  RHYNCHOCOELA FRAGS.                               06/11/78   3      1  0.07   0.108  0.00      2   0.216          X   X
4000000000F0  RHYNCHOCOELA FRAGS.                               06/11/78   1      1  0.07   0.121  0.00      2   0.242          X   X
4000000000F0  RHYNCHOCOELA FRAGS.                               06/11/78   4      1  0.07   0.014  0.00      2   0.028          X   X
                                                                    SUBTOTAL      3  0.20   0.243  0.01      6   0.486

4801000000F0       POLYCHAETA FRAG.                             06/11/78   1      1  0.07   0.190  0.01      2   0.380    X
4801000000F0       POLYCHAETA FRAG.                             06/11/78   3      1  0.07   0.138  0.00      2   0.276    X
4801000000F0       POLYCHAETA FRAG.                             06/11/78   2      1  0.07   0.076  0.00      2   0.152    X
4801000000F0       POLYCHAETA FRAG.                             06/11/78   4      1  0.07   0.107  0.00      2   0.214    X
                                                                    SUBTOTAL      4  0.27   0.511  0.02      8   1.022

480100000000       POLYCHAETA                                   06/11/78   3      3  0.20   0.003  0.00      6   0.006

480101000000            POLYNOIDAE                              06/11/78   2      1  0.07   0.072  0.00      2   0.144
480101000000            POLYNOIDAE                              06/11/78   1      2  0.14   0.003  0.00      4   0.006
                                                                    SUBTOTAL      3  0.20   0.075  0.00      6   0.150

480101050200                 EUNOE DEPRESSA                     06/11/78   1      1  0.07   0.002  0.00      2   0.004

480101050500                 EUNOE OERSTEDI                     06/11/78   1      1  0.07   0.131  0.00      2   0.262
480101050500                 EUNOE OERSTEDI                     06/11/78   2      2  0.14   0.048  0.00      4   0.096
                                                                    SUBTOTAL      3  0.20   0.179  0.01      6   0.358

480101080300                 HARMOTHOE EXTENUATA                06/11/78   1      1  0.07   0.012  0.00      2   0.024

480101080600                 HARMOTHOE IMBRICATA                06/11/78   1      1  0.07   0.121  0.00      2   0.242

480102010100                 PEISIDICE ASPERA                   06/11/78   2      2  0.14   0.006  0.00      4   0.012
480102010100                 PEISIDICE ASPERA                   06/11/78   3      7  0.47   0.056  0.00     14   0.112
480102010100                 PEISIDICE ASPERA                   06/11/78   1      6  0.41   0.038  0.00     12   0.076
                                                                    SUBTOTAL     15  1.01   0.100  0.00     30   0.200

480105010100                 PHLOE MINUTA                       06/11/78   3      5  0.34   0.006  0.00     10   0.012        X
480105010100                 PHLOE MINUTA                       06/11/78   2      1  0.07   0.001  0.00      2   0.002        X
                                                                    SUBTOTAL      6  0.41   0.007  0.00     12   0.014

480107010100                 PALEANOTUS BELLIS                  06/11/78   1      1  0.07   0.001  0.00      2   0.002
480107010100                 PALEANOTUS BELLIS                  06/11/78   2      1  0.07   0.002  0.00      2   0.004
                                                                    SUBTOTAL      2  0.14   0.003  0.00      4   0.006

480112010000                 ANAITIDES SP.                      06/11/78   3      4  0.27   0.001  0.00      8   0.002
480112010000                 ANAITIDES SP.                      06/11/78   1      4  0.27   0.002  0.00      8   0.004
480112010000                 ANAITIDES SP.                      06/11/78   4      1  0.07   0.001  0.00      2   0.002
                                                                    SUBTOTAL      9  0.61   0.004  0.00     18   0.008

480112020000                 ETEONE SP.                         06/11/78   4      3  0.20   0.027  0.00      6   0.054
480112020000                 ETEONE SP.                         06/11/78   3      4  0.27   0.005  0.00      8   0.010
                                                                    SUBTOTAL      7  0.47   0.032  0.00     14   0.064
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978

CRUISE 261 STATION 31

PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE	TAXON NAME	SAMPLE DATE	SAMP NO.	COUNT NO.	COUNT PCT	WET WEIGHT GRAMS	WET WEIGHT PCT	PER SQ METER NO.	PER SQ METER WWGT	BIT CRITERIA
480112020500	ETEONE LONGA	06/11/78	2	1	0.07	0.003	0.00	2	0.006	
480112020500	ETEONE LONGA	06/11/78	1	3	0.20	0.003	0.00	6	0.006	
		SUBTOTAL		4	0.27	0.006	0.00	8	0.012	
480122020100	PIONOSYLLIS GIGANTEA	06/11/78	2	1	0.07	0.002	0.00	2	0.004	
480122070200	EXOGONE GEMMIFERA	06/11/78	3	2	0.14	0.001	0.00	4	0.002	
480122070400	EXOGONE MOLESTA	06/11/78	1	1	0.07	0.001	0.00	2	0.002	
490123040000	NEREIS SP.	06/11/78	3	1	0.07	0.001	0.00	2	0.002	
480124010400	NEPHTYS CORNUTA	06/11/78	2	1	0.07	0.001	0.00	2	0.002	X X X X X
480124011100	NEPHTYS FERRUGINEA	06/11/78	2	1	0.07	0.132	0.00	2	0.264	
480126010100	GLYCERA CAPITATA	06/11/78	1	1	0.07	0.002	0.00	2	0.004	
480126010100	GLYCERA CAPITATA	06/11/78	3	1	0.07	0.004	0.00	2	0.008	
480126010100	GLYCERA CAPITATA	06/11/78	2	2	0.14	0.020	0.00	4	0.040	
480126010100	GLYCERA CAPITATA	06/11/78	4	1	0.07	0.010	0.00	2	0.020	
		SUBTOTAL		5	0.34	0.036	0.00	10	0.072	
480127010100	GLYCINDE PICTA	06/11/78	5	1	0.07	0.004	0.00	2	0.008	X
480127010100	GLYCINDE PICTA	06/11/78	2	4	0.27	0.009	0.00	8	0.018	X
480127010100	GLYCINDE PICTA	06/11/78	2	6	0.41	0.158	0.01	12	0.316	X
480127010100	GLYCINDE PICTA	06/11/78	1	4	0.27	0.241	0.01	8	0.482	X
480127010100	GLYCINDE PICTA	06/11/78	3	7	0.47	0.132	0.00	14	0.264	X
		SUBTOTAL		22	1.49	0.544	0.02	44	1.088	
490127010300	GLYCINDE ARMIGERA	06/11/78	4	1	0.07	0.036	0.00	2	0.072	
480130011900	LUMBRINERIS LUTI	06/11/78	1	3	0.20	0.022	0.00	6	0.044	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	2	1	0.07	0.008	0.00	2	0.016	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	3	1	0.07	0.004	0.00	2	0.008	X X X
480130011900	LUMBRINERIS LUTI	06/11/78	4	4	0.27	0.055	0.00	8	0.110	X X X
		SUBTOTAL		9	0.61	0.089	0.00	18	0.178	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	4	10	0.68	0.282	0.01	20	0.564	
480139010200	HAPLOSCOLOPLOS ELONGATUS	06/11/78	1	1	0.07	0.056	0.00	2	0.112	
		SUBTOTAL		11	0.74	0.338	0.01	22	0.676	
480142000000	SPIONIDAE	06/11/78	2	5	0.34	0.002	0.00	10	0.004	
480142040000	POLYDORA SP.	06/11/78	1	1	0.07	0.004	0.00	2	0.008	
480142040000	POLYDORA SP.	06/11/78	4	2	0.14	0.004	0.00	4	0.008	
		SUBTOTAL		3	0.20	0.008	0.00	6	0.016	
480142040500	POLYDORA CILIATA	06/11/78	3	1	0.07	0.001	0.00	2	0.002	

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                                                                                              03/25/79        PAGE   48
DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
CRUISE 261      STATION 31                                SAMPLE    SAMP      COUNT      WET WEIGHT    PER SO METER   BIT CRITERIA
                                                           DATE      NO.    NO.  PCT    GRAMS   PCT     NO.   WWGT
TAXON CODE          TAXON NAME

480142041500                 POLYDORA LIMICOLA             06/11/78    1      7   0.47   0.007  0.00     14   0.014

480142050100                 PRIONOSPIO MALMGRENI          06/11/78    2     71   4.80   0.097  0.00    142   0.194    X X   X
480142050100                 PRIONOSPIO MALMGRENI          06/11/78    3     94   6.35   0.159  0.01    188   0.318    X X   X
480142050100                 PRIONOSPIO MALMGRENI          06/11/78    1     75   5.07   0.167  0.01    150   0.334    X X   X
480142050100                 PRIONOSPIO MALMGRENI          06/11/78    4     36   2.43   0.060  0.00     72   0.120    X X   X
480142050100                 PRIONOSPIO MALMGRENI          06/11/78    5      1   0.07   0.002  0.00      2   0.004    X X   X
                                                              SUBTOTAL      277  18.72   0.485  0.02    554   0.970

480142050200                 PRIONOSPIO CIRRIFERA          06/11/78    5      1   0.07   0.001  0.00      2   0.002
480142050200                 PRIONOSPIO CIRRIFERA          06/11/78    3     10   0.68   0.002  0.00     20   0.004
480142050200                 PRIONOSPIO CIRRIFERA          06/11/78    1      3   0.20   0.004  0.00      6   0.008
480142050200                 PRIONOSPIO CIRRIFERA          06/11/78    2      4   0.27   0.004  0.00      8   0.008
                                                              SUBTOTAL       18   1.22   0.011  0.00     36   0.022

480142070100                 SPIO FILICORNIS               06/11/78    3      2   0.14   0.001  0.00      4   0.002
480142070100                 SPIO FILICORNIS               06/11/78    2      4   0.27   0.003  0.00      8   0.006
480142070100                 SPIO FILICORNIS               06/11/78    5      3   0.20   0.001  0.00      6   0.002
480142070100                 SPIO FILICORNIS               06/11/78    4     13   0.88   0.052  0.00     26   0.104
                                                              SUBTOTAL       22   1.49   0.057  0.00     44   0.114

480149000000              CIRRATULIDAE                     06/11/78    4     20   1.35   0.062  0.00     40   0.124    X X   X
480149000000              CIRRATULIDAE                     06/11/78    5      1   0.07   0.010  0.00      2   0.020    X X   X
480149000000              CIRRATULIDAE                     06/11/78    3      5   0.34   0.051  0.00     10   0.102    X X   X
480149000000              CIRRATULIDAE                     06/11/78    1      6   0.41   0.020  0.00     12   0.040    X X   X
                                                              SUBTOTAL       32   2.16   0.143  0.01     64   0.286

480149040100                 CHAETOZONE SETOSA             06/11/78    3      1   0.07   0.003  0.00      2   0.006
480149040100                 CHAETOZONE SETOSA             06/11/78    4      6   0.41   0.055  0.00     12   0.110
                                                              SUBTOTAL        7   0.47   0.058  0.00     14   0.116

480156010100                 AMMOTRYPANE AULOGASTER        06/11/78    3      2   0.14   0.049  0.00      4   0.098    X

480158010100                 CAPITELLA CAPITATA            06/11/78    1      1   0.07   0.001  0.00      2   0.002         X
480158010100                 CAPITELLA CAPITATA            06/11/78    4      1   0.07   0.003  0.00      2   0.006         X
480158010100                 CAPITELLA CAPITATA            06/11/78    5      1   0.07   0.032  0.00      2   0.064         X
                                                              SUBTOTAL        3   0.20   0.036  0.00      6   0.072

480158020000                 HETEROMASTUS SP. FRAGS        06/11/78    1     12   0.81   0.011  0.00     24   0.022

480158020100                 HETEROMASTUS FILIFORMIS       06/11/78    3     17   1.15   0.019  0.00     34   0.038      X X X X
480158020100                 HETEROMASTUS FILIFORMIS       06/11/78    2      1   0.07   0.001  0.00      2   0.002      X X X X
480158020100                 HETEROMASTUS FILIFORMIS       06/11/78    4      6   0.41   0.002  0.00     12   0.004      X X X X
                                                              SUBTOTAL       24   1.62   0.022  0.00     48   0.044

480162010200                 OWENIA FUSIFORMIS             06/11/78    3      1   0.07   0.048  0.00      2   0.096
480162010200                 OWENIA FUSIFORMIS             06/11/78    1      2   0.14   0.140  0.01      4   0.280
480162010200                 OWENIA FUSIFORMIS             06/11/78    2      2   0.14   0.008  0.00      4   0.016
480162010200                 OWENIA FUSIFORMIS             06/11/78    4      3   0.20   0.010  0.00      6   0.020
                                                              SUBTOTAL        8   0.54   0.206  0.01     16   0.412
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                              03/25/79      PAGE   49
CRUISE 261       STATION 31                                PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                           SAMPLE   SAMP      COUNT      WET WEIGHT     PER 50 METER
TAXON CODE              TAXON NAME                          DATE     NO.    NO.   PCT    GRAMS   PCT     NO.   WWGT     BIT CRITERIA
480162020100                 MYRIOCHELE HEERI              06/11/78    1      3  0.20    0.017  0.00      6   0.034
480162020100                 MYRIOCHELE HEERI              06/11/78    4     14  0.95    0.207  0.01     28   0.414
480162020100                 MYRIOCHELE HEERI              06/11/78    2      2  0.14    0.008  0.00      4   0.016
480162020100                 MYRIOCHELE HEERI              06/11/78    3      1  0.07    0.002  0.00      2   0.004
                                                              SUBTOTAL       20  1.35    0.234  0.01     40   0.468

480163010200                 IDANTHYRSUS ARMATUS           06/11/78    3     33  2.23    0.138  0.00     66   0.276
480163010200                 IDANTHYRSUS ARMATUS           06/11/78    2      3  0.20    0.031  0.00      6   0.062
480163010200                 IDANTHYRSUS ARMATUS           06/11/78    1     81  5.47    1.206  0.04    162   2.412
                                                              SUBTOTAL      117  7.91    1.375  0.05    234   2.750

480164030300                 PECTINARIA GRANULATA          06/11/78    2      5  0.34    0.262  0.01     10   0.524
480164030300                 PECTINARIA GRANULATA          06/11/78    3      4  0.27    0.490  0.02      8   0.980
480164030300                 PECTINARIA GRANULATA          06/11/78    1      2  0.14    0.096  0.00      4   0.192
                                                              SUBTOTAL       11  0.74    0.848  0.03     22   1.696

480165020000                 AMPHARETE SP.                 06/11/78    2      5  0.34    0.032  0.00     10   0.064

480165020100                 AMPHARETE ARCTICA             06/11/78    5      4  0.27    0.021  0.00      8   0.042
480165020100                 AMPHARETE ARCTICA             06/11/78    1      3  0.20    0.042  0.00      6   0.084
                                                              SUBTOTAL        7  0.47    0.063  0.00     14   0.126

480165040100                 LYSIPPE LABIATA               06/11/78    1      2  0.14    0.003  0.00      4   0.006

480168000000             SABELLIDAE                        06/11/78    3      1  0.07    0.001  0.00      2   0.002
480168000000             SABELLIDAE                        06/11/78    4     13  0.88    0.017  0.00     26   0.034
480168000000             SABELLIDAE                        06/11/78    1      1  0.07    0.001  0.00      2   0.002
                                                              SUBTOTAL       15  1.01    0.019  0.00     30   0.038

480168140100                 LAONOME KROYERI               06/11/78    4      6  0.41    0.030  0.00     12   0.060

480170010200                 CHITINOPOMA GROENLANDICA      06/11/78    3      2  0.14    0.001  0.00      4   0.002
480170010200                 CHITINOPOMA GROENLANDICA      06/11/78    1      2  0.14    0.002  0.00      4   0.004
                                                              SUBTOTAL        4  0.27    0.003  0.00      8   0.006

480170040000                 SERPULA SP.                   06/11/78    1      1  0.07    0.017  0.00      2   0.034

480170050300                 SPIRORBIS SEMIDENTATUS        06/11/78    3      9  0.61    0.003  0.00     18   0.006
480170050300                 SPIRORBIS SEMIDENTATUS        06/11/78    1     12  0.81    0.044  0.00     24   0.088
                                                              SUBTOTAL       21  1.42    0.047  0.00     42   0.094

480200000000         OLIGOCHAETA                           06/11/78    1      7  0.47    0.002  0.00     14   0.004
480200000000         OLIGOCHAETA                           06/11/78    2      4  0.27    0.004  0.00      8   0.008
                                                              SUBTOTAL       11  0.74    0.006  0.00     22   0.012

490300000000         POLYPLACOPHORA                        06/11/78    1      1  0.07    0.031  0.00      2   0.062

490402020100                 NUCULA TENUIS                 06/11/78    3      1  0.07    0.001  0.00      2   0.002
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 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                        03/25/79       PAGE   50
                                                             PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
 CRUISE 761      STATION 31
                                                               SAMPLE   SAMP       COUNT       WET WEIGHT     PER SQ METER   BIT CRITERIA
 TAXON CODE           TAXON NAME                                DATE     NO.     NO.   PCT    GRAMS   PCT       NO.   WWGT

 490403050000               YOLDIA SP.                        06/11/78    3        1  0.07   0.045  0.00        2  0.090
 490403050000               YOLDIA SP.                        06/11/78    2        1  0.07   0.003  0.00        2  0.006
                                                                 SUBTOTAL          2  0.14   0.048  0.00        4  0.096

 490407020100               CRENELLA DESSUCATA                06/11/78    2        1  0.07   0.002  0.00        2  0.004

 490407060000               MODIOLUS SP.                      06/11/78    3        1  0.07   0.018  0.00        2  0.036
 490407060000               MODIOLUS SP.                      06/11/79    2        3  0.20   0.071  0.00        6  0.142
 490407060000               MODIOLUS SP.                      06/11/78    1        2  0.14   0.227  0.01        4  0.454
                                                                 SUBTOTAL          6  0.41   0.316  0.01       12  0.632

 490410010100               PODODESMUS MACROCHISMA            06/11/78    3        1  0.07   0.001  0.00        2  0.002

 490415020000               AXINOPSIDA SP.                    06/11/78    3       14  0.95   0.133  0.00       28  0.266   X X X X
 490415020000               AXINOPSIDA SP.                    06/11/78    2       27  1.82   0.220  0.01       54  0.440   X X X X
 490415020000               AXINOPSIDA SP.                    06/11/78    1        6  0.41   0.066  0.00       12  0.132   X X X X
 490415020000               AXINOPSIDA SP.                    06/11/78    5        1  0.07   0.002  0.00        2  0.004   X X X X
 490415020000               AXINOPSIDA SP.                    06/11/79    4      176 11.89   0.823  0.03      352  1.646   X X X X
                                                                 SUBTOTAL        224 15.14   1.244  0.04      448  2.488

 490420010000               CLINOCARDIUM SP.                  06/11/78    1        1  0.07   0.006  0.00        2  0.012
 490420010000               CLINOCARDIUM SP.                  06/11/79    2       22  1.49   0.346  0.01       44  0.692
                                                                 SUBTOTAL         23  1.55   0.352  0.01       46  0.704

 490424010000               MACOMA SP.                        06/11/79    3       15  1.01   0.200  0.01       30  0.400       X   X
 490424010000               MACOMA SP.                        06/11/78    1        9  0.61   0.340  0.01       18  0.680       X   X
 490424010000               MACOMA SP.                        06/11/79    2       15  1.01   0.228  0.01       30  0.456       X   X
 490424010000               MACOMA SP.                        06/11/78    4        8  0.54   0.610  0.02       16  1.220       X   X
 490424010000               MACOMA SP.                        06/11/78    5        1  0.07   0.002  0.00        2  0.004       X   X
                                                                 SUBTOTAL         48  3.24   1.380  0.05       96  2.760

 490428020000               MYA SP.                           06/11/78    2        3  0.20   0.043  0.00        6  0.086
 490428020000               MYA SP.                           06/11/78    3        2  0.14   0.016  0.00        4  0.032
 490428020000               MYA SP.                           06/11/78    1        2  0.14   0.020  0.00        4  0.040
                                                                 SUBTOTAL          7  0.47   0.079  0.00       14  0.158

 490429020000               HIATELLA SP.                      06/11/79    1       14  0.95   1.283  0.05       28  2.566
 490429020000               HIATELLA SP.                      06/11/78    3        6  0.41   0.168  0.01       12  0.336
 490429020000               HIATELLA SP.                      06/11/78    2       10  0.68   0.592  0.02       20  1.184
 490429020000               HIATELLA SP.                      06/11/78    4        1  0.07   0.011  0.00        2  0.022
                                                                 SUBTOTAL         31  2.09   2.054  0.07       62  4.108

 490500000000          GASTROPODA                             06/11/78    4        1  0.07   0.009  0.00        2  0.018
 490500000000          GASTROPODA                             06/11/78    2        1  0.07   0.002  0.00        2  0.004
 490500000000          GASTROPODA                             06/11/78    3        1  0.07   0.005  0.00        2  0.010
                                                                 SUBTOTAL          3  0.20   0.016  0.00        6  0.032

 490504020000               COLISELLA SP.                     06/11/78    3        1  0.07   0.002  0.00        2  0.004
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
CRUISE 761      STATION 31                              PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                          SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE           TAXON NAME                            DATE     NO.   NO.   PCT    GRAMS   PCT    NO.     WWGT     BIT CRITERIA

490505010100                    CRYPTOBRANCHIA CONCENTRICA  06/11/78  3     12  0.81   1.571  0.06    24     3.142
490505010100                    CRYPTOBRANCHIA CONCENTRICA  06/11/78  1     19  1.28   1.374  0.05    38     2.748
490505010100                    CRYPTOBRANCHIA CONCENTRICA  06/11/78  2      2  0.14   0.010  0.00     4     0.020
                                                               SUBTOTAL     33  2.23   2.955  0.11    66     5.910

490506040200                    SOLARIELLA OBSCURA          06/11/78  2      4  0.27   0.507  0.02     8     1.014
490506040200                    SOLARIELLA OBSCURA          06/11/78  3      2  0.14   0.095  0.00     4     0.190
                                                               SUBTOTAL      6  0.41   0.602  0.02    12     1.204

490507020100                    MOELLERIA QUADRAI           06/11/78  2      1  0.07   0.003  0.00     2     0.006

490511010000                    SOLARIELLA SP.              06/11/78  3      3  0.20   0.027  0.00     6     0.054
490511010000                    SOLARIELLA SP.              06/11/78  1      1  0.07   0.012  0.00     2     0.024
490511010000                    SOLARIELLA SP.              06/11/78  2      1  0.07   0.005  0.00     2     0.010
                                                               SUBTOTAL      5  0.34   0.044  0.00    10     0.088

490530040000                    TROPHONOPSIS SP.            06/11/78  2      1  0.07   0.032  0.00     2     0.064

490576010000                    SIPHONARIA SP.              06/11/78  3      1  0.07   0.006  0.00     2     0.012

530000000000     CRUSTACEA                                  06/11/78  3      1  0.07   0.268  0.01     2     0.536       X
530000000000     CRUSTACEA                                  06/11/78  5      1  0.07   0.002  0.00     2     0.004       X
                                                               SUBTOTAL      2  0.14   0.270  0.01     4     0.540

531802010000                    BALANUS SP.                 06/11/78  3      9  0.61   1.204  0.04    18     2.408       X   X

531802010400                    BALANUS CRENATUS            06/11/78  1    182 12.301720.000 62.02   3643440.000     X X X X
531802010400                    BALANUS CRENATUS            06/11/78  2     58  3.921031.500 37.19   1162063.000     X X X X
                                                               SUBTOTAL    240 16.222751.500 99.22   4805503.000

532800000000        CUMACEA                                 06/11/78  2      1  0.07   0.001  0.00     2     0.002
532800000000        CUMACEA                                 06/11/78  3      2  0.14   0.003  0.00     4     0.006
                                                               SUBTOTAL      3  0.20   0.004  0.00     6     0.008

533100000000        AMPHIPODA                               06/11/78  4      1  0.07   0.008  0.00     2     0.016
533100000000        AMPHIPODA                               06/11/78  5      1  0.07   0.001  0.00     2     0.002
533100000000        AMPHIPODA                               06/11/78  3     23  1.55   0.028  0.00    46     0.056
533100000000        AMPHIPODA                               06/11/78  2     23  1.55   0.179  0.01    46     0.358
533100000000        AMPHIPODA                               06/11/78  1     14  0.95   0.019  0.00    28     0.038
                                                               SUBTOTAL     62  4.19   0.235  0.01   124     0.470

533311000000             PAGURIDAE                          06/11/78  3      1  0.07   0.026  0.00     2     0.052
533311000000             PAGURIDAE                          06/11/78  2      1  0.07   0.693  0.02     2     1.386
                                                               SUBTOTAL      2  0.14   0.719  0.03     4     1.438

533311020000                    PAGURUS SP.                 06/11/78  1      1  0.07   0.295  0.01     2     0.590

533317010100                    OREGONIA GRACILIS           06/11/78  3      1  0.07   2.978  0.11     2     5.956
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978
CRUISE 261      STATION 31                                                             03/25/79      PAGE   52
                                                 PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
TAXON CODE            TAXON NAME                   SAMPLE   SAMP      COUNT      WET WEIGHT     PER SQ METER
                                                    DATE     NO.    NO.  PCT     GRAMS   PCT     NO.   WWGT     BIT CRITERIA
590101020100                 PHASCOLION STROMBI      06/11/78    1      1  0.07    0.007  0.00      2   0.014
680204010100                 ALLOCENTROTUS FRAGILIS  06/11/78    1      3  0.20    0.199  0.01      6   0.398
680309000000              OPHIURIDAE                 06/11/78    2      1  0.07    0.006  0.00      2   0.012
791613000000              PHOLIDIDAE                 06/11/78    2      1  0.07    0.419  0.02      2   0.838       X   X
                                                 STATION TOTAL     1480       2773.256        29605546.512
                                                 SIMPSON INDEX 0.096444          SHANNON DIVERSITY INDEX 3.014152
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 DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                            03/25/79      PAGE   53
 CRUISE 261        STATION 7                                  PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                               SAMPLE   SAMP     COUNT      WET WEIGHT    PER SQ METER
TAXON CODE            TAXON NAME                                DATE     NO.   NO.  PCT    GRAMS   PCT     NO.   WWGT    BIT CRITERIA

4801000000F0        POLYCHAETA FRAG.                          06/12/78    2     1  0.09   0.015  0.01       2   0.030   X
4801000000F0        POLYCHAETA FRAG.                          06/12/78    5     1  0.09   0.036  0.02       2   0.072   X
4801000000F0        POLYCHAETA FRAG.                          06/12/78    3     1  0.09   0.139  0.08       2   0.278   X
4801000000F0        POLYCHAETA FRAG.                          06/12/78    4     1  0.09   0.023  0.01       2   0.046   X
4801000000F0        POLYCHAETA FRAG.                          06/12/78    1     1  0.09   0.012  0.01       2   0.024   X
                                                                 SUBTOTAL       5  0.43   0.225  0.13      10   0.450

480101000000            POLYNOIDAE                            06/12/78    1     4  0.34   0.022  0.01       8   0.044
480101000000            POLYNOIDAE                            06/12/78    4     2  0.17   0.021  0.01       4   0.042
480101000000            POLYNOIDAE                            06/12/78    3     5  0.43   0.053  0.03      10   0.106
                                                                 SUBTOTAL      11  0.94   0.096  0.06      22   0.192

480101020200                ANTINOELLA SARSI                  06/12/78    2     2  0.17   0.023  0.01       4   0.046

480101150200                POLYNOE GRACILIS                  06/12/78    5     2  0.17   0.010  0.01       4   0.020

480105010100                PHLOE MINUTA                      06/12/78    1     1  0.09   0.020  0.01       2   0.040     X
480105010100                PHLOE MINUTA                      06/12/78    5     1  0.09   0.001  0.00       2   0.002     X
                                                                 SUBTOTAL       2  0.17   0.021  0.01       4   0.042

480112020500                ETEONE LONGA                      06/12/78    5     1  0.09   0.001  0.00       2   0.002

480120010200                GYPTIS BREVIPALPA                 06/12/78    3     1  0.09   0.004  0.00       2   0.008
480120010200                GYPTIS BREVIPALPA                 06/12/78    5     1  0.09   0.001  0.00       2   0.002
                                                                 SUBTOTAL       2  0.17   0.005  0.00       4   0.010

480124010400                NEPHTYS CORNUTA                   06/12/78    5    15  1.28   0.049  0.03      30   0.098   X X X X X
480124010400                NEPHTYS CORNUTA                   06/12/78    1     4  0.34   0.009  0.01       8   0.018   X X X X X
480124010400                NEPHTYS CORNUTA                   06/12/78    3    15  1.28   0.042  0.03      30   0.084   X X X X X
480124010400                NEPHTYS CORNUTA                   06/12/78    2     2  0.17   0.004  0.00       4   0.008   X X X X X
480124010400                NEPHTYS CORNUTA                   06/12/78    4    11  0.94   0.045  0.03      22   0.090   X X X X X
                                                                 SUBTOTAL      47  4.00   0.149  0.09      94   0.298

480124011100                NEPHTYS FERRUGINEA                06/12/78    1     2  0.17   1.641  0.98       4   3.282

:480127010100               GLYCINDE PICTA                    06/12/78    3     1  0.09   0.002  0.00       2   0.004   X

480130011900                LUMBRINERIS LUTI                  06/12/78    2     4  0.34   0.100  0.06       8   0.200   X X   X
480130011900                LUMBRINERIS LUTI                  06/12/78    5    10  0.85   0.063  0.04      20   0.126   X X   X
480130011900                LUMBRINERIS LUTI                  06/12/78    4     5  0.43   0.049  0.03      10   0.098   X X   X
480130011900                LUMBRINERIS LUTI                  06/12/78    3     5  0.43   0.045  0.03      10   0.090   X X   X
480130011900                LUMBRINERIS LUTI                  06/12/78    1    11  0.94   0.145  0.09      22   0.290   X X   X
                                                                 SUBTOTAL      35  2.98   0.402  0.24      70   0.804

480139010200                HAPLOSCOLOPLOS ELONGATUS          06/12/78    2     1  0.09   0.035  0.02       2   0.070
480139010200                HAPLOSCOLOPLOS ELONGATUS          06/12/78    5     3  0.26   0.074  0.04       6   0.148
480139010200                HAPLOSCOLOPLOS ELONGATUS          06/12/78    1     2  0.17   0.041  0.02       4   0.082
                                                                 SUBTOTAL       6  0.51   0.150  0.09      12   0.300
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                                   03/25/79       PAGE   54
 CRUISE 261      STATION 7                                  PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION

TAXON CODE               TAXON NAME                           SAMPLE   SAMP     COUNT      WET WEIGHT     PER SQ METER
                                                               DATE     NO.    NO.  PCT    GRAMS   PCT      NO.   WWGT    BIT CRITERIA
480140020400                   ARICIDEA JEFFREYSII            06/12/78   4       5  0.43   0.015  0.01      10   0.030
480140020400                   ARICIDEA JEFFREYSII            06/12/78   3       3  0.26   0.008  0.00       6   0.016
480140020400                   ARICIDEA JEFFREYSII            06/12/78   5      15  1.28   0.041  0.02      30   0.082
480140020400                   ARICIDEA JEFFREYSII            06/12/78   2       4  0.34   0.020  0.01       8   0.040
480140020400                   ARICIDEA JEFFREYSII            06/12/78   1       5  0.43   0.011  0.01      10   0.022
                                                                  SUBTOTAL      32  2.72   0.095  0.06      64   0.190

480142050100                   PRIONOSPIO MALMGRENI           06/12/78   2       5  0.43   0.051  0.03      10   0.102    X X   X
480142050100                   PRIONOSPIO MALMGRENI           06/12/78   5       2  0.17   0.004  0.00       4   0.008    X X   X
480142050100                   PRIONOSPIO MALMGRENI           06/12/78   1       3  0.26   0.038  0.02       6   0.076    X X   X
480142050100                   PRIONOSPIO MALMGRENI           06/12/78   4       3  0.26   0.029  0.02       6   0.058    X X   X
480142050100                   PRIONOSPIO MALMGRENI           06/12/78   3       4  0.34   0.071  0.04       8   0.142    X X   X
                                                                  SUBTOTAL      17  1.45   0.193  0.12      34   0.386

480142050200                   PRIONOSPIO CIRRIFERA           06/12/78   4       7  0.60   0.005  0.00      14   0.010
480142050200                   PRIONOSPIO CIRRIFERA           06/12/78   1       1  0.09   0.008  0.00       2   0.016
480142050200                   PRIONOSPIO CIRRIFERA           06/12/79   3       1  0.09   0.002  0.00       2   0.004
480142050200                   PRIONOSPIO CIRRIFERA           06/12/79   5       6  0.51   0.004  0.00      12   0.008
                                                                  SUBTOTAL      15  1.28   0.019  0.01      30   0.038

480149000000              CIRRATULIDAE                        06/12/78   2       2  0.17   0.009  0.01       4   0.018    X X   X
480149000000              CIRRATULIDAE                        06/12/78   4       1  0.09   0.002  0.00       2   0.004    X X   X
480149000000              CIRRATULIDAE                        06/12/78   1       3  0.26   0.008  0.00       6   0.016    X X   X
480149000000              CIRRATULIDAE                        06/12/78   5       1  0.09   0.002  0.00       2   0.004    X X   X
480149000000              CIRRATULIDAE                        06/12/79   3       1  0.09   0.002  0.00       2   0.004    X X   X
                                                                  SUBTOTAL       8  0.68   0.023  0.01      16   0.046

480149040100                   CHAETOZONE SETOSA              06/12/78   1       1  0.09   0.001  0.00       2   0.002

480155010100                   SCALIBREGMA INFLATUM           06/12/78   4      96  8.16   6.899  4.11     192  13.798    X X X X X
480155010100                   SCALIBREGMA INFLATUM           06/12/78   5     228 19.39  24.708 14.73     456  49.416    X X X X X
480155010100                   SCALIBREGMA INFLATUM           06/12/78   1     220 18.71  10.238  6.11     440  20.476    X X X X X
480155010100                   SCALIBREGMA INFLATUM           06/12/78   2     172 14.63  16.272  9.70     344  32.544    X X X X X
480155010100                   SCALIBREGMA INFLATUM           06/12/78   3      69  5.87   5.126  3.06     138  10.252    X X X X X
                                                                  SUBTOTAL     785 66.75  63.243 37.71    1570 126.486

480156010100                   AMMOTRYPANE AULOGASTER         06/12/78   1       1  0.09   0.081  0.05       2   0.162    X
480156010100                   AMMOTRYPANE AULOGASTER         06/12/78   4       6  0.51   0.302  0.18      12   0.604    X
480156010100                   AMMOTRYPANE AULOGASTER         06/12/79   3       6  0.51   0.273  0.16      12   0.546    X
480156010100                   AMMOTRYPANE AULOGASTER         06/12/78   5      12  1.02   0.646  0.39      24   1.292    X
480156010100                   AMMOTRYPANE AULOGASTER         06/12/79   2       2  0.17   0.098  0.06       4   0.196    X
                                                                  SUBTOTAL      27  2.30   1.400  0.83      54   2.800

480158020100                   HETEROMASTUS FILIFORMIS        06/12/78   5      25  2.13   0.193  0.12      50   0.386      X X X X
480158020100                   HETEROMASTUS FILIFORMIS        06/12/78   2      19  1.62   0.498  0.30      38   0.996      X X X X
480158020100                   HETEROMASTUS FILIFORMIS        06/12/78   3      14  1.19   0.686  0.41      28   1.372      X X X X
480158020100                   HETEROMASTUS FILIFORMIS        06/12/78   4      23  1.96   0.087  0.05      46   0.174      X X X X
480158020100                   HETEROMASTUS FILIFORMIS        06/12/79   1       9  0.77   0.516  0.31      18   1.032      X X X X
                                                                  SUBTOTAL      90  7.65   1.980  1.18     180   3.960
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DUTCH HARBOR BENTHIC GRAB DATA -- JUNE 1978                                      03/25/79     PAGE   59
 CRUISE 261      STATION 7                          PERCENTS REFER TO TOTAL COLLECTIONS AT THIS STATION
                                                       SAMPLE   SAMP     COUNT     WET WEIGHT   PER SQ METER
 TAXON CODE            TAXON NAME                       DATE     NO.   NO.  PCT   GRAMS   PCT    NO.   WWGT    BIT CRITERIA
 4904000000F0      PELECYPODA FRAGS.                  06/12/78    3      1  0.09  0.647   0.39     2   1.294
 4904000000F0      PELECYPODA FRAGS.                  06/12/78    1      1  0.09  0.037   0.02     2   0.074
                                                         SUBTOTAL        2  0.17  0.684   0.41     4   1.368

 490400000000      PELECYPODA                         06/12/78    2      1  0.09  0.159   0.09     2   0.318

 490403020300              NUCULANA FOSSA             06/12/78    3      1  0.09  0.056   0.03     2   0.112       X   X

 490403050000              YOLDIA SP.                 06/12/78    1      1  0.09  0.003   0.00     2   0.006
 490403050000              YOLDIA SP.                 06/12/78    3      3  0.26  0.006   0.00     6   0.012
 490403050000              YOLDIA SP.                 06/12/78    4      2  0.17  0.004   0.00     4   0.008
 490403050000              YOLDIA SP.                 06/12/78    5      1  0.09  0.003   0.00     2   0.006
                                                         SUBTOTAL        7  0.60  0.016   0.01    14   0.032

 490415020000              AXINOPSIDA SP.             06/12/73    5     21  1.79  0.103   0.06    42   0.206   X X X X
 490415020000              AXINOPSIDA SP.             06/12/78    4     14  1.19  0.034   0.02    28   0.068   X X X X
 490415020000              AXINOPSIDA SP.             06/12/78    1      8  0.68  0.016   0.01    16   0.032   X X X X
 490415020000              AXINOPSIDA SP.             06/12/78    3     16  1.36  0.037   0.02    32   0.074   X X X X
 490415020000              AXINOPSIDA SP.             06/12/79    2      2  0.17  0.018   0.01     4   0.036   X X X X
                                                         SUBTOTAL       61  5.19  0.208   0.12   122   0.416

 490424010000              MACOMA SP.                 06/12/78    1      1  0.09 13.650   8.14     2  27.300       X   X
 490424010000              MACOMA SP.                 06/12/78    3      2  0.17 14.846   8.85     4  29.692       X   X
 490424010000              MACOMA SP.                 06/12/78    4      1  0.09 61.274  36.54     2 122.548       X   X
 490424010000              MACOMA SP.                 06/12/78    5      2  0.17  7.101   4.23     4  14.202       X   X
                                                         SUBTOTAL        6  0.51 96.871  57.77    12 193.742

 530000000000  CRUSTACEA                              06/12/78    5      1  0.09  0.005   0.00     2   0.010       X
 530000000000  CRUSTACEA                              06/12/78    4      1  0.09  0.005   0.00     2   0.010       X
                                                         SUBTOTAL        2  0.17  0.010   0.01     4   0.020

 533100000000        AMPHIPODA                        06/12/78    4      3  0.26  0.012   0.01     6   0.024
 533100000000        AMPHIPODA                        06/12/78    5      1  0.09  0.001   0.00     2   0.002
 533100000000        AMPHIPODA                        06/12/78    1      1  0.09  0.001   0.00     2   0.002
                                                         SUBTOTAL        5  0.43  0.014   0.01    10   0.028

                                                    STATION TOTAL     1176      167.697         2352 335.394

                                                    SIMPSON INDEX 0.458069       SHANNON DIVERSITY INDEX 1.469269




 SUCCESSFUL FOJ.
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APPENDIX B

TAXON CODES AND SPECIES NAMES USED IN THE CLUSTER ANALYSES DESCRIBED IN THIS REPORT

TAXON CODES IN SORTED ORDER	TAXA
48010102000	NEMIDIA SP.
48010102020	ANTINOELLA SARSI
48010105020	EUNOE DEPRESSA
48010105050	EUNOE OERSTEDI
48010108030	HARMOTHOE EXTENUATA
48010108060	HARMOTHOE IMBRICATA
48010115020	POLYNOE GRACILIS
48010117010	HESPERONOE COMPLANATA
48010201010	PEISIDICE ASPERA
48010501010	PHOLOE MINUTA
48010503000	STHENELAIS SP.
48010504000	SIGALION SP.
48010701010	PALEANOTUS BELLIS
48011201000	ANAITIDES SP.
48011202000	ETEONE SP.
48011202050	ETEONE LONGA
48012001020	GYPTIS BREVIPALPA
48012202000	SYLLIS SP.
48012202010	PIONOSYLLIS GIGANTEA
48012207020	EXOGONE GEMMIFERA
48012207040	EXOGONE MOLESTA
48012304000	NEREIS SP.
48012401040	NEPHTYS CORNUTA
48012401050	NEPHTYS PUNCTATA
48012401110	NEPHTYS FERRUGINEA
48012601010	GLYCERA CAPITATA
48012701010	GLYCINDE PICTA
48012701030	GLYCINDE ARMIGERA
48012702020	GONIADA MACULATA
48012801030	ONUPHIS IRIDESCENS
48013001010	LUMBRINERIS BICIRRATA
48013001190	LUMBRINERIS LUTI
48013901000	HAPLOSCOLOPLOS SP.
48013901020	HAPLOSCOLOPLOS ELONGATUS
48013903000	SCOLOPLOS FULIGINOSA
48014002040	ARICIDEA JEFFREYSII
48014202000	LAONICE SP.
48014204050	POLYDORA CILIATA
48014204150	POLYDORA LIMICOLA
48014205000	PRIONOSPIO SP.
48014205010	PRIONOSPIO MALMGRENI
48014205020	PRIONOSPIO CIRRIFERA
48014207010	SPIO FILICORNIS
48014210000	SPIOPHANES SP.
48014210010	SPIOPHANES BOMBYX
48014210020	SPIOPHANES KROYERI
48014210030	SPIOPHANES CIRRATA
48014301020	MAGELONA PACIFICA
48014301050	MAGELONA LONGICORNIS
48014903000	THARYX SP.
48014904010	CHAETOZONE SETOSA
48015201030	BRADA INHABILIS
48015501010	SCALIBREGMA INFLATUM
48015601010	AMMOTRYPANE AULOGASTER
48015801010	CAPITELLA CAPITATA
48015802010	HETEROMASTUS FILIFORMIS
48015802020	HETEROMASTUS GIGANTEUS
48015803000	NOTOMASTUS SP.
48015803060	NOTOMASTUS LAERIATUS
48016109010	AXIOTHELLA CATENATA
48016109020	PRAXILLELLA PRAETERMISSA
48016201020	OWENIA FUSIFORMIS
48016202010	MYRIOCHELE HEERI

48016301020	IDANTHYRSUS ARMATUS
48016403030	PECTINARIA GRANULATA
48016502000	AMPHARETE SP.
48016502010	AMPHARETE ARCTICA
48016504010	LYSIPPE LABIATA
48016505010	MELINNA CRISTATA
48016701010	TEREBELLIDES STROEMII
48016801030	CHONE CINCTA
48016814010	LAONOME KROYERI
48017001020	CHITINOPOMA GROENLANDICA
48017004000	SERPULA SP.
48017005030	SPIRORBIS SEMIDENTATUS
48017501010	COSSURA LONGOCIRRATA
49040202010	NUCULA TENUIS
49040302000	NUCULANA SP.
49040302030	NUCULANA FOSSA
49040304000	TINDARIA SP.
49040305070	YOLDIA THRACIAEFORMIS
49040306000	YOLDIELLA SP.
49040702010	CRENELLA DECUSSATA
49040706000	MODIOLUS SP.
49040706010	MODIOLUS MODIOLUS
49041001010	PODODESMUS MACROCHISMA
49041502000	AXINOPSIDA SERRICATA
49041503010	THYASIRA FLEXUOSA
49041601000	DIPLODONTA SP.
49041601020	DIPLODONTA ALEUTICA
49041801000	MYSELLA SP.
49042001000	CLINOCARDIUM SP.
49042001010	CLINOCARDIUM CILIATUM
49042002010	SERRIPES GROENLANDICUS
49042105010	PSEPHIDIA LORDI
49042301000	SPISULA SP.
49042301010	SPISULA POLYNYMA
49042401010	MACOMA CALCAREA
49042401030	MACOMA BROTA
49042401070	MACOMA MOESTA MOESTA
49042401130	MACOMA CARLOTTENSIS
49042402010	TELLINA LUTEA
49042807000	MYA SP.
49042907000	HIATELLA SP.
49043307000	LYONSIA SP.
49043502000	THRACIA SP.
49043502050	THRACIA BERINGI
49050401000	ACMAEA SP.
49050402000	COLISELLA SP.
49050501010	CRYPTOBRANCHIA CONCENTRICA
49050604000	SOLARIELLA SP.
49050604020	SOLARIELLA OBSCURA
49050702010	MOELLERIA QUADRAI
49051101000	SOLARIELLA SP.
49051103000	CINGULA SP.
49053004000	TROPHONOPSIS SP.
49054104000	OENOPOTA SP.
49054501000	RETUSA SP.
49057601000	SIPHONARIA SP.
53180201000	BALANUS SP.
53180201040	BALANUS CRENATUS
53280403040	EUDORELLOPSIS DEFORMIS
53310201010	AMPELISCA MACROCEPHALA
53313414000	HIPPOMEDON
53313429000	ORCHOMENE SP.
53313708000	MONOCULODES SP.
53314207000	PARAPHOXUS SP.
53330401060	PANDALUS HYPSINOTUS
53331107000	PAGURUS SP.
53331701010	OREGONIA GRACILIS
53332103000	PINNIXA SP.
59010101010	GOLFINGIA MARGARITACEA
59010102010	PHASCOLION STROMBI
68020101010	ECHINARACHNIUS PARMA
68020401010	ALLOCENTROTUS FRAGILIS

APPENDIX C

FEATURES OF STATIONS SAMPLED IN THE VICINITY OF DUTCH HARBOR, ALASKA 11-12 JUNE 1978, BY THE INSTITUTE OF MARINE SCIENCE, UNIVERSITY OF ALASKA, FAIRBANKS, ALASKA BASED ON FIELD NOTES OF H. FEDER, TELEVISION OBSERVATIONS AND DATA DERIVED FROM LABORATORY ANALYSIS OF GRAB SAMPLES. NOT ALL SAMPLES HAVE BEEN ANALYZED.

T.V. = Television Observation on Shipboard, Grab = van Veen Grab,
Polychaetous Annelid = PA, C = Clam and S = Snail

A. Stations with samples processed, and taxonomic determinations, numbers of individuals and biomass available for this report. Stations are grouped according to cluster analysis of *ln* transformed data (see Fig. 4 and Table 17). All species in grab samples are included in Appendices A, B, and D.

STATION GROUP 1

Station DUT-0A, 29M

(1) T.V. - shell fragments noted on the bottom, a snow crab, *Chionoecetes* sp., observed moving on the bottom. Sand-shell; silty sand tan-brown to gray sticky.

(2) Grab - moderate sulfide odor; shell fragments. Few organisms observable in screened samples on shipboard.

(3) Laboratory analysis of grab samples - dominant species

Nephtys cornuta (PA) - Abundant
Scalibregma inflatum (PA) - Few
Axinopsida serricata (C) - Few
Ammotrypane aulogaster (PA) - Few
No other species present

Species present were primarily deposit feeders

Station DUT-02, 30M

(1) T.V. - a large amount of fine sediment observed as T.V. camera contacted bottom; bottom not as black as at DUT 01A (see below); sediment surface reflected some light.

(2) Grabs - black sediment with strong sulfide odor; screened more readily than DUT 01A. Shell common. No living organisms observable in screened sample on shipboard.

(3) Laboratory analysis of grab samples - dominant species

Nephtys cornuta (PA) - Abundant
Scalibregma inflatum (PA) - Few
No other species present

Species present were deposit feeders.

Station DUT 00, 34M

(1) TV - showed lighter bottom. A snow crab and several fish (round fish) observed.

(2) Grabs - sediment black; strong sulfide smell. No observable living organisms in screened samples on shipboard.

(3) Laboratory analysis - dominant species in grab samples.

Nephtys cornuta (PA) - Common
Unidentified crab - Few
No other species present

The one infaunal species present is a deposit feeder.

Station DUT 01A, Station in Dutch Harbor behind spit, 28M

(1) TV not able to show bottom - presumably due to black sulfide deposits.

(2) Grabs showed black sediment with very strong sulfide smell. Water during washing process was foamy black. Sediment fine and difficult to screen. One replicate had dead juvenile fish; moribund but fresh in appearance. Many clam shells. One replicate had no organisms.

Nephtys cornuta (PA) - Common
Spiophanes bombyx (PA) and *Capitella capitata* (PA) - Few; both deposit feeders
Only one other organism, a burrowing clam collected

Species present are deposit feeders.

STATION GROUP 2

Station 3H, 34M

(1) TV showed light colored bottom; observed 1 roundfish; particulate matter common.

(2) Four grabs were black; strong sulfide smell; sandy silt; large amount of macroalgal debris. One grab sandy with no sulfide odor detectable; very little plant material. One replicate had no organisms observable.

(3) Laboratory analysis of grab samples - dominant species.

Nephtys cornuta (PA) - Few to Common
Other polychaetous annelids - Few

Clams - Few
Pandalus hypsinotus (coonstripe shrimp) - Two specimens

Species present primarily deposit feeders.

STATION GROUP 3

Station 3BF, 58M

(1) TV - too deep for television

(2) Grabs - sandy-silt firmly held together; brownish gray with fine layer on top of tannish material (2-3 cm thick); fishy smell or marine organic smell. Large amount of terrestrial plant debris made samples difficult to wash. After washing, a large amount of debris was left behind (terrestrial plant). Very few organisms were observable in screened samples.

(3) Laboratory analysis of grab samples - dominant species

Four species of polychaetous annelids
  (Cirratulidae, *Chaetozone setosa*,
  Scalibregma inflatum, *Heteromastus*
  filiformis) - Common to Abundant
Two species of polychaetes - Few
Axinopsida serricata (C) - Common
Yoldia thraciaeformis (C) - One large individual
Three other species of clams - Few

Deposit - feeding polychaetous annelids and clams few to common.

Station 3C, 68M

(1) TV - too deep for television

(2) Grabs - silty sand, tan in color; mild organic smell, sticky. Shell common. Oxic.

(3) Laboratory analysis of grab samples - dominant species

Polychaetous annelids - Few to Abundant
  - the most common polychaetes, were *Prionospio malmgreni*,
    Cirratulidae, *Scalibregma inflatum*, *Heteromastus filiformis*
Nuculanidae (C)- Common
Axinopsida serricata (C) - Common
Yoldia thraciaeformis, *Spisula* sp., *Macoma* spp. - Few
Gastropods, amphipods, decapods - Few

Deposit-feeding polychaetes and clams common to abundant.

Station HEL-7, 98M

(1) TV - too deep for television

(2) Grabs - grey-brown silt; no obvious odor; few *Macoma* fragments; sediment readily washed through screens.

(3) Laboratory analysis of grab samples - dominant species

Polychaetous annelids - Few to Abundant
- the most common polychaetes were *Nephtys cornuta, Lumbrineris luti, Scalibregma inflatum* (abundant) *Heteromastus filiformis*

Axinopsida serricata (C) - Common
Yoldia sp. (C) and *Macoma* sp. (C) - Few
Amphipod crustaceans - Few

Deposit-feeding polychaetes and clams common to abundant.

STATION GROUP 4

Station 3B, 51M

(1) TV - no observation made

(2) Grabs - silty sand; mild organic smell, but no sulfide odor. Sand color - tannish gray. Grabs were full, and difficult to wash through the screen. Shells of *Macoma* spp. common.

(3) Laboratory analysis of grab samples, - dominant species.

Polychaetous annelids - Few to Abundant
- the most common polychaetes were *Nephtys cornuta, Glycinde picta, Lumbrineris luti, Prionospio malmgreni, Spiophanes kroyeri*, Cirratulidae, *Scalibregma inflatum, Heteromastus filiformis, Notomastus* sp., *Axiothella catenata.*

Nucula tenuis (C) - Few
Nuculana fossa (C) - Few
Axinopsida serricata (C) - Abundant
Amphipods, hermit crabs, *Pinnixa* sp.
(pea crab), Ophiuroid (brittle star) - Few

Deposit-feeding polychaetes and clams few to common. Few large errant polychaetes.

Station 3F - Approximately 100M off underwater location of Vita Food Products Outfall, 51M. Pipe broken, and was apparently discharging onshore.

(1) TV - no observation made

(2) Grabs - sandy, clean. Organic smell but no sulfide odor detectable.

(3) Laboratory analysis of grab samples - dominant species.

Polychaetous annelids - Few to Abundant
- the most common polychaetes were *Glycinde picta, Lumbrineris luti, Prionospio malmgreni, Spiophanes kroyeri, S. cirrata, Magelona pacifica, Scalibregma inflatum, Capitella capitata, Heteromastus filiformis, Axiothella catenata, Chone cincta*

Clams present but only few of a variety of species such as *Nucula tunuis, Nuculana fossa, Axinopsida serricata, Macoma calcarea*

Golfingia margaritacea (sipunculid) - Few

A variety of deposit and suspension feeding species present.

Station HEL-3, 49M

(1) TV - no observations made

(2) Grabs - silt gray-brown in color; mild organic odor; sticky composition with *Chlamys beringana, Pandora gigantea, Macoma* spp., *Clinocardium* sp., *Nuculana* sp., *Mya* valves and shell fragments.

(3) Laboratory analysis of grab samples - dominant species

Polychaetous annelids - Few to Abundant
- the most common polychaetes were *Glycinde picta, Lumbrineris luti, Scoloplos fuliginosa, Polydora* sp., *Prionospio malmgreni, Spio filicornis, Magelona pacifica*, Cirratulidae, *Tharyx* sp., *Scalibregma inflatum, Heteromastus filiformis, Notomastus* sp., Maldanidae, *Axiothella catenata, Ampharete arctica, Chone cincta*

Clams - Common to Abundant
- the most common clams were *Nucula tenuis, Nuculana fossa, Axinopsida serricata*

Amphipods - Abundant

Golfingia margaritacea, brittle stars, *Solariella* spp. - Few

Deposit feeders very common

Station HEL-3A, 40M

(1) TV - no observation

(2) Grabs - organic smell, no sulfide; silty-sand, tannish gray.

(3) Laboratory analysis of grab samples - dominant species

Polychaetes - Few to Abundant. Fewer species than Station HEL-3.
- the most common polychaetes were *Nephtys ferruginea*, *Glycinde picta*, *Lumbrineris luti*, *Haploscoloplos elongatus*, *Prionospio malmgreni*

Clams - Few to Abundant
- the most common clams were *Spisula* sp., *Macoma* sp., *Mya* sp.

Solariella obscura (S) - very common
Balanus sp. - abundant and found in only one replicate
Amphipoda - very common
Ophiuroids - few

Deposit and suspension feeding species common.

STATION GROUP 5

Station 3G, off Pan Alaska - Whitney Fidalgo Outfall, 31M

(1) TV - clean bottom, sandy-silt; small amount of fine sediment observable in overlying water after frame hit bottom. Just before frame contacted bottom, the camera passed through a school of shrimp (probably *Pandalus hypsinotus*, the coonstripe shrimp). When the frame settled down, fish moved into and out of the frame - possibly the eel pout *Lycodes diapterus*. The fish were vigorous. The area appeared healthy and surface was light and appeared oxic.

(2) Grabs - sandy, black sediment. Strong sulfide odor, but not as strong as at 3E. Reduced number of species.

(3) Laboratory analysis of grab samples - dominant species.

Polychaetes annelids - few to abundant, patchy. Fewer species than in 3F or 3A.
- the most common polychaetes were *Lumbrineris luti*, *Haploscoloplos elongatus*, *Prionospio malmgreni*, *Tharyx* sp.

Clams - few to common; the most abundant species were *Axinopsida serricata*
Mya sp. also common

Solariella sp. - few present

Deposit-feeding polychaetes dominant

STATION GROUP 6

Station 31, 31M

(1) TV - showed dense population of shrimps - probably *Pandalus hypsinotus*.

(2) Grabs - all had small pebbles to large cobbles. No sulfide noted. Crushed shell and sand mixture. Small volume of samples = 4-5L. Acorn barnacles numerous, limpets common. The most diverse station sampled.

(3) Laboratory analysis of grab samples - dominant species

Polychaetes annelids - few to abundant
- the most common polychaetes were *Glycinde picta*, *Prionospio malmgreni*, Cirratulidae, *Heteromastus filiformis*, *Myriochele heeri*, *Idanthyrus armatus*, Sabellidae, *Spirorbis semidentatus*

Clams - few to abundant
- the most common clams were *Axinopsida serricata*, *Clinocardium* sp., *Macoma* sp., *Hiatella* sp.

Limpets - few to common; *Cryptobranchia concentrica* - very common
Snails - few of several species; *Solariella* spp. most common
The barnacle *Balanus crenatus* - abundant
Amphipoda, hermit crabs, *Oregonia gracilis* (crab), *Allocentrotus fragilis* (sea urchin), brittle stars - few of each
Gunnel (fish) - 1 specimen

Suspension feeders common at this station.

STATION GROUP 7

Station DUT-OB, 22M

(1) TV - sandy bottom with humps that appear to be produced by animals. Some shell, some amphipods. Bottom appears clean. Species diversity high number of polychaete species reduced. Clams common.

(2) Grabs - very clean sand, no organic odor, some shell. Oxic.

(3) Laboratory analysis of grab samples - dominant species

Foraminifera - very abundant
Polychaetous annelids - few; number of species and number of individuals of each species low
- the most common polychaetes were *Nephtys ferruginea*, *Glycinde* spp., *Lumbrineris bicirrata*, *Haploscoloplos elongatus*, Spionidae, *Magelona longicornis*, Cirratulidae

Clams - few to very common
- the most common clams were *Spisula* sp., *Axinopsida serricata*
- also present were *Psephidia lordi*, *Macoma moesta*, *Lyonsia* sp., *Thracia* sp., *Tellina lutea*

Snails - few; *Solariella obscura* and *Cingula* sp., *Retusa* sp.
Cumaceans - few; *Eudorellopsis deformis*
Amphipoda - common
Sea urchins - few to common; includes *Allocentrotus fragilis*

Deposit and suspension feeding species common.

B. Station processed, but only one grab taken; not included in cluster analysis.

Station 02A, 27.5M

(1) TV - light, gray bottom, no sign of animal castings or burrows. Large amount of debris present in the water column.

(2) Grab - sulfide odor, but not strong as in 3DE or 3E (see below). One specimen of each of the following species of polychaetes present: *Pholoe minuta, Nephtys cornuta, Scalibregma inflatum*.

C. Stations located on or immediately adjacent to the Universal Seafood Outfall.

Station 3E. Station was directly over the Universal Seafood Outfall; the discharge was periodic with crab debris welling up to the water surface. 11-16M

(1) TV - showed many crustacean fragments in water column. TV on bottom buried in sediment initially - when TV unit pulled up, could not see bottom due to black sediment. No living organisms observed.

(2) Grabs - only 1 grab taken; nauseating H_2S odor. Surface of grab material covered with several centimeters of fresh processing waste layered over many centimeters of old black waste and cobble. Difficult to wash. When washed only black shells, black debris, remained in screen. Strong sulfide smell. No organisms present.

(3) Laboratory analysis of grab samples - no organisms present.

Station 3DE, 28M

(1) TV - large amount of debris in water column indicating proximity to effluent outflow. When frame on bottom, it was apparent that it landed on an effluent pile (the effluent surface discharge was about 100 m off); large amounts of processing debris moved out to the water when the frame contacted the bottom.

(2) Grabs - came up full of processing wastes. No organisms present.

(3) Laboratory analysis of grab samples - no organisms present.

D. Stations unprocessed. Only field observations available.

Station 3J, 14M

(1) TV - showed very little.

(2) Grabs - Fine gravel and cobbles. Only 2 grabs obtained. Many grabs attempted.
    - 1 polychaete
    - 3 amphipods

Station 2A, 14-27.5M

(1) TV - No observations

(2) Grabs at 14M. Samples of rock collected; organism attached:
    - coralline algae
    - chitons
    - few brittle stars
    - compound tunicate

Grabs at 27.5M - Sulfide odor but not as strong as at Station 3E. No observation of screened material available.

Station 2B, 14M

(1) TV - No observation

(2) Grab - No grab samples. Large rocks only. No epifauna.

Station 3AG, 38M

(1) TV - considerable debris in water. On approach of camera to the bottom several fish swam away; as frame hit bottom fine sediments

were stirred up and soon settled revealing 18-20 *Pandalus hypsinotus* (coonstripe shrimp). The shrimp remained within the TV frame - some swimming in and out; as frame moved, shrimps moved. The impression is that the bottom has large numbers of these shrimp present. Impression of a clean silty-sand, oxic bottom.

(2) Grabs - Light colored, silty-sand (mainly sand); appears somewhat "gelatinous", very clean - oxic. Slight to strong organic odor. No sulfide odor. Considerable plant debris. No sign of processing wastes. Large *Macoma* shells common.

- few polychaetes
- few clams
- some large, healthy looking *Macoma* sp.

Station 3D, 57M

(1) TV - No TV

(2) Grabs - All grabs full with worm tubes projecting from the mud. Sediment - tannish with some black coloration; silty sand; "fishy" organic smell; in two grabs shell held grab jaws open slightly.

- in grabs: *Macoma* sp., *Pododesmus macrochisma* and *Mytilus* sp. shell fragments; some plant material (blackened); small amount unidentifiable black debris - none with sulfide odor. Noticeable fishy odor as material concentrated by washing in screen box. Sediments oxic with healthy appearing fauna in 3 replicates; sulfide smell in last 2 grabs, but fauna healthy and same as above. One grab had juvenile snow crab in sulfide - smelling sediment, crab healthy in appearance.
- Polychaetes - F to C; *Macoma* sp. - few; *Nuculana* sp. - few; Maldanidae - common; *Solariella* sp. - few.
- Several plastic garbage bags, strapping material, pieces of lumber (ship), piece of kelp.

Station 3C1, 48M

(1) No TV

(2) Grabs - Silty sand; brown-tan color; mild organic odor; sticky composition; numerous shell fragments.

- few anemones
- Maldanidae - common
- *Nephtys* sp. - rare

- polychaetes - common
- *Nuculana* sp. - common
- polychaete tubes - rare

Station HEL 2, 17M

(1) No TV observation

(2) No grab samples collected. Rocky bottom. Rocks had encrusting sponge, bryozoans, chitons.

Station 1A, 46M

(1) No TV

(2) Grabs - Bottom sandy, cobble

(3) No sulfide smell, organic smell. Clean area, very patchy.

- some replicates in sand, others in cobble. Species observed in replicates vary from one grab to another. A diversity of epifaunal (on rock) and infaunal species collected.
- many barnacles.
- 1 lg. *Serripes groenlandicus*
- few *Ophiura* sp.
- 1 *Cistenides* sp.
- few Bryozoa
- few *Macoma* spp.
- few *Laqueus*(?) sp.
- few polychaetes
- few chitons, limpets
- 1 *Natica* sp.

Station HEL 1, 80M

(1) No TV

(2) Grabs - Dark - sandy-silt - held together well.

(3) Rich organic odor but no sulfide. Rich fauna.

- few *Cyclocardia crassidens*?
- few *Clinocardium ciliatum*
- many polychaetes
- worm tubes
- *Nuculana* sp.
- 1 *Musculus* sp.
- few amphipods

Station 7A, 80M

(1) No TV

(2) Grabs - Silty-clay, black gray, mild organic odor. Sticky composition *Macoma, Nuculana* fragments unidentified shell fragments.

- common *Ophelia* sp.
- common polychaete
- rare *Macoma* sp.

Station 7B, 51M

(1) No TV

(2) Grabs - Sandy-silt; no odor; large amount of organic debris - mainly plant.

- polychaetes (Capitellidae, few *Scalibregma inflatum*, 1 large errant polychaete) - few to common

Station HEL-6, 132M

(1) No TV

(2) Grabs - Silt-clay, tan; sticky mud. No odor. Some plant debris. Oxic.

- polychaetes - common (*Scalibregma inflatum* and some Capitellidae)
- *Macoma* spp. - few to common
- *Axinopsida serricata* - few to common
- *Nuculana* sp. - few

Station HEL-4, 95M

(1) No TV

(2) Grabs - Silty-clay-sand, sticky composition, brown-black-gray, *Yoldia* and *Macoma* shell fragments, organic odor. No sulfide odor.

- polychaete worms - few
- Maldanidae
- *Macoma intermedia*?

Station HEL-4A, 78M

(1) No TV

(2) Grabs - One taken. No data available on biota.

APPENDIX D

DOMINANT SPECIES AT STATIONS WITHIN STATION GROUPS. DOMINANCE OF SPECIES BY NUMBERS ONLY.

APPENDIX D

DOMINANT SPECIES AT STATIONS WITHIN STATION GROUPS. DOMINANCE OF SPECIES BY NUMBERS ONLY.

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 1			
DUT 0A	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
DUT 02	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
DUT 00	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
DUT 01A	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
Station Group 2			
3H	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
Station Group 3			
3BF	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
	Prionospio spp.	Annelida, Polychaeta, Spionidae	Segmented Worm
	Cirratulidae	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Chaetozone setosa	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Scalibregma inflatum	Annelida, Polychaeta, Scalibregmidae	Segmented Worm
	Heteromastus filiformis	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Axinopsida serricata	Mollusca, Pelecypoda Thyasiridae	Clam

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 3			
3C	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
	Prionospio malmgreni	Annelida, Polychaeta, Spionidae	Segmented Worm
	Cirratulidae	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Scalibregma inflatum	Annelida, Polychaeta, Scalibregmidae	Segmented Worm
	Heteromastus filiformis	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Clam
HEL 7	*Nephtys cornuta*	Annelida, Polychaeta, Nephtyidae	Segmented Worm
	Lumbrineris luti	Annelida, Polychaeta, Lumbrineridae	Segmented Worm
	Aricidea jeffreysii	Annelida, Polychaeta, Paraonidae	Segmented Worm
	Scalibregma inflatum	Annelida, Polychaeta, Scalibregmidae	Segmented Worm
	Ammotrypane aulogaster	Annelida, Polychaeta, Opheliidae	Segmented Worm
	Heteromastus filiformis	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Clam
Station Group 4			
3B	*Lumbrineris luti*	Annelida, Polychaeta, Lumbrineridae	Segmented Worm
	Prionospio malmgreni	Annelida, Polychaeta, Spionidae	Segmented Worm

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 4 (continued)			
3B	*Spiophanes kroyeri*	Annelida, Polychaeta, Spionidae	Segmented Worm
	Cirratulidae	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Heteromastus filiformis	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Notomastus sp.	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Axiothella catenata	Annelida, Polychaeta, Maldanidae	Segmented Worm
	Nucula tenuis	Mollusca, Pelecypoda, Nuculidae	Protobranch clam
	Nuculana fossa	Mollusca, Pelecypoda, Nuculanidae	Protobranch clam
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Clam
3F	*Glycinde picta*	Annelida, Polychaeta, Goniadidae	Segmented Worm
	Lumbrineris luti	Annelida, Polychaeta, Lumbrineridae	Segmented Worm
	Prionospio malmgreni	Annelida, Polychaeta, Spionidae	Segmented Worm
	Spiophanes kroyeri	Annelida, Polychaeta, Spionidae	Segmented Worm
	Spiophanes cirrata	Annelida, Polychaeta, Spionidae	Segmented Worm
	Magelona pacifica	Annelida, Polychaeta, Magelonidae	Segmented Worm
	Tharyx sp.	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Scalibregma inflatum	Annelida, Polychaeta, Scalibregmidae	Segmented Worm

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 4			
3F	*Capitella capitata*	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Heteromastus filiformis	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Axiothella catenata	Annelida, Polychaeta, Maldanidae	Segmented Worm
	Chone cincta	Annelida, Polychaeta, Sabellidae	Segmented Worm
	Nuculana fossa	Mollusca, Pelecypoda, Nuculanidae	Protobranch clam
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Clam
3	*Glycinde picta*	Annelida, Polychaeta, Goniadidae	Segmented Worm
	Lumbrineris luti	Annelida, Polychaeta, Lumbrineridae	Segmented Worm
	Scoloplos fuliginosa	Annelida, Polychaeta, Orbiniidae	Segmented Worm
	Spionidae	Annelida, Polychaeta, Spionidae	Segmented Worm
	Prionospio malmgreni	Annelida, Polychaeta, Spionidae	Segmented Worm
	Spio filicornis	Annelida, Polychaeta, Spionidae	Segmented Worm
	Magelona pacifica	Annelida, Polychaeta, Magelonidae	Segmented Worm
	Cirratulidae	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Scalibregma inflatum	Annelida, Polychaeta, Scalibregmidae	Segmented Worm
	Heteromastus filiformis	Annelida, Polychaeta, Capitellidae	Segmented Worm

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 4 (continued)			
3	Capitellidae	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Maldanidae	Annelida, Polychaeta, Maldanidae	Segmented Worm
	Chone cincta	Annelida, Polychaeta, Sabellidae	Segmented Worm
	Nucula tenuis	Mollusca, Pelecypoda, Nuculidae	Protobranch clam
	Nuculana fossa	Mollusca, Pelecypoda, Nuculanidae	Protobranch clam
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Protobranch clam
	Amphipoda	Arthropoda, Crustacea	Sand flea
3A	*Glycinde picta*	Annelida, Polychaeta, Goniadidae	Segmented Worm
	Lumbrineris luti	Annelida, Polychaeta, Lumbrineridae	Segmented Worm
	Haploscoloplos elongatus	Annelida, Polychaeta, Orbiniidae	Segmented Worm
	Prionospio malmgreni	Annelida, Polychaeta, Spionidae	Segmented Worm
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Clam
	Spisula sp.	Mollusca, Pelecypoda, Mactridae	Clam
	Mya sp.	Mollusca, Pelecypoda, Myidae	Clam
	Solariella obscura	Mollusca, Gastropoda, Trochidae	Snail

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 4 (continued)			
3A	Amphipoda	Arthropoda, Crustacea	Sand flea
Station Group 5			
3G	*Lumbrineris luti*	Annelida, Polychaeta, Lumbrineridae	Segmented Worm
	Prionospio malmgreni	Annelida, Polychaeta, Spionidae	Segmented Worm
	Tharyx sp.	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Clam
Station Group 6			
3I	*Glycinde picta*	Annelida, Polychaeta, Goniadidae	Segmented Worm
	Prionospio malmgreni	Annelida, Polychaeta, Spionidae	Segmented Worm
	Spio filicornis	Annelida, Polychaeta, Spionidae	Segmented Worm
	Cirratulidae	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Heteromastus filiformis	Annelida, Polychaeta, Capitellidae	Segmented Worm
	Myriochele heeri	Annelida, Polychaeta, Owenidae	Segmented Worm
	Idanthyrus armatus	Annelida, Polychaeta, Sabellariidae	Segmented Worm
	Sabellidae	Annelida, Polychaeta, Sabellidae	Segmented Worm
	Spirorbis semidentatus	Annelida, Polychaeta, Serpulidae	Segmented Worm

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 6 (continued)			
3I	*Axinopsida serricata*	Mollusca, Pelecypoda, Thyasiridae	Clam
	Macoma sp.	Mollusca, Pelecypoda, Tellinidae	Clam
	Clinocardium sp.	Mollusca, Pelecypoda, Cardiidae	Cockle
	Hiatella sp.	Mollusca, Pelecypoda, Hiatellidae	Clam
	Cryptobranchia concentrica	Mollusca, Gastropoda, Lepetidae	Limpet
	Balanus crenatus	Arthropoda, Crustacea, Balanidae	Barnacle
	Amphipoda	Arthropoda, Crustacea,	Sand flea
Station Group 7			
DUT OB	Foraminifera	Protozoa, Foraminifera	none
	Haploscoloplos elongatus	Annelida, Polychaeta, Orbiniidae	Segmented Worm
	Spiophanes bombyx	Annelida, Polychaeta, Spionidae	Segmented Worm
	Magelona longicornis	Annelida, Polychaeta, Magelonidae	Segmented Worm
	Cirratulidae	Annelida, Polychaeta, Cirratulidae	Segmented Worm
	Axinopsida serricata	Mollusca, Pelecypoda, Thyasiridae	Clam
	Spisula sp.	Mollusca, Pelecypoda, Mactridae	Clam
	Cingula sp.	Mollusca, Gastropoda, Littorinidae	Snail

Station	Abundant Species	Taxonomic Categories	Common Name
Station Group 7 (continued)			
DUT 0B	*Eudorellopsis deformis*	Arthropoda, Crustacea, Cumacea	none
	Amphipoda	Arthropoda, Crustacea	Sand flea
	Strongylocentrotidae	Echinodermata, Echinoidea Strongylocentrotidae	Sea urchin

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Washington, D.C. 20235

October 5, 1979

F:PB:F7:YB

Mr. Albert J. Erickson
Acting, Deputy Assistant Administrator
for Water Planning and Standards
Environmental Protection Agency (WH-551)
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. Erickson:

As I indicated to Mr. Swep Davis in my letter of June 15, 1979, the National Marine Fisheries Service (NMFS) is interested in commenting on EPA's mandated report to Congress on the environmental impacts of seafood effluents (Section 74, Clean Water Act of 1977). Subsequently, we were informally requested by your staff to review the basic reports on which the final report is to be based.

As a result, we have made some general reviews of these reports, which I have enclosed. Our overall view is that although seafood processing wastes cannot be shown to be significantly beneficial to the environment, neither can it be said that they pose a uniform threat under conditions outlined in the studies. We feel that more data are needed to establish firm baselines upon which to draw these conclusions. Therefore, further and more comprehensive research is necessary. We would hope that such factors are noted in your summary report to Congress.

The environmental aspects of seafood waste discharges are of deep concern to this agency. We are striving to protect our nation's living marine resources and their habitats while at the same time not jeopardizing the development of our fishery resources. The conclusions drawn as a result of EPA's Section 74 seafood study could, therefore, be critical in formulating long range seafood waste disposal policies which adequately address environmental concerns in terms of full utilization of fishery resources, as well as costs in terms of impacts on the industry and the consumers.

We appreciate the opportunity to comment on these basic reports and look forward to reviewing and commenting on the final summary report to Congress.

Sincerely yours,

Terry L. Leitzell
Assistant Administrator
for Fisheries

Enclosure

National Marine Fisheries Service
Comments on Reports Submitted by Environment Protection Agency
Under Section 74 of PL 95-217

1. Benthic Macrofauna Sediment and Water Quality Near Seafood Cannery Outfalls in Kenai and Cordova, Alaska, final report, dated February 15, 1979, by SCS Engineers, Long Beach, California, under contract number 68-03-2578.

COMMENT:

An informative but hardly adequate study of the two areas considering the problems of sampling and the need at each site to reconcile observations with natural conditions. Particularly at Kenai, it appears that water and benthic sampling and analysis achieve little if not related to natural benthic conditions (page 86). In Cordova the observations of local waste accumulations with no observed effects on dissolved oxygen values simply verifies the stratification of water above the bottom in a tidal environment. The problem of how to distribute and minimize the benthic impact was not studied but should be if long-term solutions to waste handling are to be developed.

2. Benthic Macrofauna, Sediment and Water Quality Near Seafood Cannery Outfalls in Yaquina Bay, Oregon, dated January 29, 1979, by the Marine and Fresh Water Ecology Branch, Corvallis Environmental Research Laboratory, EPA, Marine Science Center, Newport, Oregon

COMMENT:

A brief but adequate study of the limited effects of waste discharge in a harbor with excellent flushing action. Although the visual or esthetic effects of the effluent plumes were noted, the investigators did not observe any biological or benthic effects with one exception. In their discussion (page 3 of Discussion and Conclusions) they suggest additional study of intertidal fauna and flora beneath the cannery docks. This would seem to be a useful extension of the work for a longer-term understanding of ecological effects in the harbor.

3. An Investigation of Certain Aspects of Crab Processing Wastes Disposal Practices: Insitu and in Vitro Responses of Vibrio Parahemoliticus and Vibrio Anguillarum, prepared by the University of Alaska.

COMMENT:

The first four conclusions of this study (page 2) are useful and factual; however, the extrapolation to "hazardous to humans" and "hazardous to fish and ....fauna" in Conclusions 5 and 6 are unwarranted interpretations. Obviously, vibrio and other pathogenic organisms might be shown to survive and grow in the accumulated crab wastes; however, this knowledge does not create a hazard unless a reasonable probability or epidemiology can be constructed. This was not done by the investigators. The single finding of V. alginolytious is important but in our judgement is insufficient to raise the hazard flag.

4. Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Water at Dutch Harbor, Alaska, prepared by the Institute of Marine Science, University of Alaska under contract number R803922-03-1, dated April 1, 1979.

COMMENT:

The study clearly showed the adverse impact of accumulated wastes in the areas adjacent to the outfalls of the processing plants but also reported that the broad areas near outfalls were not impacted at present. The conclusion of the investigators is that eventually the broad areas will be adversely affected. This may be a reasonable assumption, but it appears that better documentation is needed. There should be a more adequate documentation of the ecological effects of continued dumping in the nearshore environment. The recommendations of the report (page 9) appear reasonable and suggest that studies should proceed to better evaluate the alternatives - i.e. ecology of important marine environments, industry economics, and other involved factors. We note that the investigators comment (page 23) that the anoxic bottom conditions observed are at least in part attributed to oceanographic-meteorological conditions not well understood, particularly since the sampling and field study has not been conducted on a year-round-basis. This also suggests that the longer-term study is needed. In the absence of a sanitary health crisis (suggested but not documented) or a broad ecological impact, some reasonable alternatives for amelioration of the industry dumping practices might be proposed while further studies proceed as recommended. Alternatively, the processors may be faced with difficult and uneconomic alternatives for either waste treatment or dumping in offshore distribution areas. This study does not provide the technological alternatives as suggested by Section 74. From an overall viewpoint the report appears to add no new understanding or dimensions to the problem of localized accumulations of processed waste in a discharge area of limited tidal-current flow. The study was short and intense (24 hours in June 1978) but extrapolates much based on previous limited studies and general understanding of the problem.

5. Draft Report Market Feasibility Study of Seafood Waste Reduction in Alaska, prepared by Development Planning and Research Associates, Manhattan, Kansas.

COMMENT:

The report lacks a summary and conclusions section. It also lacks a statement that tells the purpose of the study. The title implies it is a study on the feasibility of marketing fish meal and oil produced in Alaska.

Actually, the report is: (1) an estimate of the economic losses that would be incurred by fish-reduction operations in Alaska and (2) a comparison with the cost of barging seafoods wastes to dump sites, The report concludes that in three locations, Ketchikan, Seward, and Kodiak, it would probably be better to operate reduction plants than to barge the wastes to deep water. Just a cursory examination of the data presented leads the reader to question whether or not this conclusion is realistic. In table IV-10 on page IV-16 the Ketchikan plant size is given as 50 tons per day. In appendix Table II-1 the estimated seafood wastes are given at 7.3 million pounds. This waste is available during a 4-month period with the major amount available in August, which is estimated at 3.7 million pounds. This would require a 50-ton-per-day plant to exceed its production capacity by about 10 tons a day during the entire month of August. Compare this with the Petersburg situations where waste is available year around and a reduction plant capable of handling most of the waste available already exists. Yet this plant has apparently not operated at a profit. Can a plant to be located in Ketchikan for only 4 months of the year be expected to turn a profit? How would operation of such a plant on a four months basis compare economically with operation of barge equipment on the same time frame?

6. Technology for Seafood Processing Waste Treatment and Utilization, Section 74 Seafood Processing Study, prepared by the E.C. Jordan Company, Portland, Maine, under contract number 68-01-4831, dated February 1979.

COMMENT:

A good survey of the alternatives for seafood waste control, treatment, and utilization, with no surprises or new solutions. The disposal of liquid wastes and sludges on land is reviewed, but the costs of pick-up and distribution and the limitation of its use on agricultural and forest lands are treated insufficiently, particularly the economics. The discussion of the need of industry to start with in-plant waste separation and control is good. More helpful would be detailed studies of specific plant operations and waste output in relation to costs. This is particularly important in relating alternatives for conversion of wastes to protein hydrolysates, silage, liquid fertilizers, and fish meal. The discussion of waste reduction in Alaska fails to emphasize the very real problem of high operating costs, low returns, and negative profit. Costs of barging in Alaska should be treated more realistically.

7. Ecological Changes in Outer Los Angeles-Long Beach Harbors Following Initiation of Secondary Waste Treatment and Cessation of Fish Cannery Waste Effluent by Dr. Dorothy Soule.

COMMENT:

In all fairness to Dr. Soule and her colleagues, it must be recognized that (1) the task attempted by her, conclusively demonstrating postcessation changes, is extremely difficult and (2) logic suggests that removing the energy rich cannery effluent should result in some of the changes she believes occurred. Because natural conditions vary so much, it is extremely difficult to describe a base line. Numerous years of study are needed and often a true base line may not exist. Yet Dr. Soule was forced to base her comparisons on just a few studies made before cessation and on studies made during a very brief period after cessation. Naturally, some differences were shown, but it would be virtually impossible--in the statistical and scientific sense--to prove conclusively that cessation caused the changes. The problem may not be whether or not organic wastes will result in bioenhancement, but, rather how much organic matter can a given body of water receive. The uniqueness of each body of water makes it difficult to pre-determine this amount of organic matter that can be placed in it without resulting in "too much" having been added.

Further, logic suggests that the addition and then removal of the energy rich cannery wastes from the system produce changes in the system. Fertilization, natural and artificial, is a well known and fairly well understood phenomenon. It is extremely unlikely that removal of the cannery wastes would not cause major changes in the system. We believe that the questions of what are these changes and how long will adjustment of the system take are not yet answered.

In our review of the Harbors Environmental Project report, we sought the answers to the following question:

1. Were there true differences between biological conditions before and after the cessation of dumping of cannery effluent into the harbor?

2. If there were differences, were these directly attributable to cessation?

And, finally, an entirely different type of question.

3. If differences attributable to cessation occurred, were they desirable or undesirable?

With respect to the first and second questions, our conclusion is that although some differences in pre- and post-cessation survey results exist, that, by and large, these cannot be conclusively attributed to removal of untreated cannery wastes from the system. Numerous factors influence fish distribution and abundance. Both the great decrease in larval abundance and the change in partyboat fishery success are better explained by other factors, year-class failure on the one hand, and long-term decline related to fishing pressure on the other. The "creel census" which purported to show decreased success of shore anglers appeared too imprecise to determine real change. It does seem possible that white croaker populations did decline but as mentioned by others, they also may have only dispersed after no attractant was available. Finally, fish populations vary in response to numerous factors which are often undetected by man. Changes of the magnitude described by Soule can be expected to occur normally.

The bird population "changes" are no more conclusive. About half of the species increased while major decreases were only in scoters and gulls. Migratory waterfowl are notably unpredictable and the scoter count offers little information about the local environment. Reductions in the number of gulls may have resulted from their dispersion after dumping ceased.

With reference to the third question posed, we believe that even if the harbor environment is less rich now than before dumping ceased, conditions over the long run may improve. It seems that too little time has been available for adjustment.

Finally, we believe that even if long-term changes have occurred as a result of cessation of dumping, these changes are not necessarily undesirable. Fertilization can enhance productivity, however, it also may create conditions that are undesirable for some species.

PACIFIC SEAFOOD PROCESSORS ASSOCIATION
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April 16, 1979

Mr. Calvin J. Dysinger
Effluent Guidelines Divison (WH-552)
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Cal:

Enclosed are comments by the Pacific Seafood Processors Association on the Section 74 Seafood Study reports titled:

X "Benthic Macrofanna, Sediment and Water Quality Near Seafood Cannery Outfalls in Kenai and Cordova, Alaska" by SCS Engineering, February 15, 1979.

✓ "An Investigation of Certain Aspects of Crab Processing Waste Disposal Practices: In Situ and in Vitro Responses of Vibrio Parahemoliticus and Vibrio Anuillarum", 1978.

✓ "Interim Report to Environmental Protection Agency of the Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Water at Dutch Harbor, Alaska" by Howard Feder and David Burrell, University of Alaska, October 1, 1978.

X "Benthic Macrofanna, Sediment and Water Quality Near Seafood Cannery Outfalls in Yaquina Bay, Oregon" by Environmental Protection Agency, Marine Science Center, Newport, Oregon, January 29, 1979.

Since these reports are site specific for Oregon and Alaska it was felt that comments by the Pacific Seafood Processors Association, whose members operate in these areas, would be most appropriate. These companies are also members of the Nationa Food Processors Association which has recently submitted comments on the other Section 74 contractor's reports that have nationwide implications.

In addition to our comments on the contractor's reports, we are including copies of the following additional material which we feel should be considered in the Section 74 Study.

✓ "Ecological Changes in Outer Los Angeles-Long Beach Harbors Following Initiation of Secondary Waste Treatment and

Cessation of Fish Cannery Waste Effluent" by Institute for Marine and Coastal Studies, A-lan Hancock Foundation, Los Angeles, California, April 1979.

"Biological and Water Quality Implications of Current Crab Processing Waste Disposal Practies in Dutch Harbor, Alaska", by Dr. Timothy J. Bechtel, March 1979.

X "Investigation of Crab Waste Disposal Alternatives in Dutch Harbor, Alaska", by Brown and Caldwell Consulting Engineers, March 1979.

We with to thank you for keeping us involved in the study procedure and for the extention of the comment period which was necessary for the completion of our submission. We hope that when you have completed your review of the contractor's reports and the public comments, we will be given the opportunity to review and comment on your draft Section 74 Seafood Study Report.

Very truly yours,

Roger A. DeCamp
Technical Director

RAD/ch

encl.

Comments by the Pacific Seafood Processors Association on the Oregon and Alaska Site Specific Reports for the Section 74 Seafood Study.

The Pacific Seafood Processors Association represents the majority of the seafood processors in Alaska, Washington and Oregon. As such the Association is vitally concerned in the Section 74 Seafood Study mandated by Congress in the 1977 Clean Water Act, Public Law 95-217. This Act required the U. S. Environmental Protection Agency to conduct a study to determine the effects of seafood processing waste on the receiving waters as follows.

SEC. 74. The Administrator of the Environmental Protection Agency shall conduct a study to examine the geograpical, hydrological, and biological characteristics of marine waters to determine the effects of seafood processes which dispose of untreated natural wastes into such waters. In addition, such study shall examine technologies which may be used in such processes to facilitate the use of the nutrients in these wastes or to reduce the discharge of such wastes into the marine environment. The results of such study shall be submitted to Congress not later than January 1, 1979.

Comments on Report Titled "Benthic Macrofanna, Sediment and Water Quality Near Seafood Cannery Outfa-ls In Kenai and Cordova, Alaska" by SCS Engineering, February 15, 1979.

This report by SCS Engineering represents a significant portion of the Section 74 Study and, as such, the industry is most concerned about the conclusions drawn from this investigation. We have several general comments on the report and also several comments concerning specific points in the text.

General Comments

1. This study represents the worst possible conditions that would be encountered at the sites visited. The investigators arrived at the peak of the season or shortly thereafter and, because of this, they sampled at a time in which the impacts, if any, of the seafood waste would be most marked. Had the investigaors been able to continue the study over a longer time span, it is likely that the conditions observed would have been similar to those noted at the NEFCO outfalls which had not been operating for several months at the time of the study.

2. It must be noted that, although the study was limited to benthic organisms, there was abundant evidence of pelagic species and other marine life in the areas of the discharges which were not observed at the non-discharge sites. The final report should acknowledge the presence of these fishes and crustaceans as well as noting the results of the benthic studies.

3. It is most unfortunate that during the period the Cordova plants were visited, several of the plants were encountering mechanical difficulties with their waste-discharge systems. In

these instances, the study is actually more an indication of the effects of the discharge of whole, unground waste than that of the discharge of waste ground to the size required by the NPDS Permits for Remote Alaska locations, namely one-half inch in size.

Specific Comments

Page 3. It should be noted that both the 1966 University of Alaska Study and the Brickell and Goering Study were measuring the effects of unground waste discharged into Iliuliuk Bay which is an area of very poor water circulation. The industry has since moved its discharge points from this location to Unalaska Bay on the seaward side of Amaknak Island. This relocation was done by industry in an attempt to prevent a problem from developing in the Bay similar to that which occurred in Kodiak's St. Paul Harbor. Unalaska Bay has superior circulation and water exchange rate compared to Iliuliuk Bay. The conditions noted in these studies for that body of water no longer exist.

Page 3. The Brickell and Goering work at Little Port Walter shows that the Alaskan receiving waters naturally receive loadings of seafood material in excess of that discharged by seafood processing plants. It must be remembered that there are many more salmon spawning streams than there are processors in the state.

Page 4. The Dutch Harbor surveys mentioned will be discussed in the comments concerning the University of Alaska's Interim Interim Report to the EPA titled, "Impact of Seafood Cannery

Page 4.

Waste on the Benthic Biota and Adjacent Water at Dutch Harbor, Alaska" and in the additional material submitted by this Association.

Page 5. Reference is made to the EPA Region X Study on the Pollution Problem from Shellfish Processor Discharges in Kodiak Harbor, St. Paul Harbor and Gibson Cove, Alaska. It should be remembered that Kodiak represented a unique situation where a large number of processing plants were discharging into a body of water which had a poor circulation pattern. Moreover, these plants were unique in that they were operating on a year-round basis with shrimp and crab comprising the majority of the products processed. For these reasons, the Kodiak situation developed into a considerable problem. To remedy this situation tangential screens were installed by the Kodiak processors and, it should be noted, that conditions in the St. Paul Harbor area have improved considerably over those noted during the 1971 investigations.

A document which should have been included in the literature review was the report titled " Evaluation of Waste Disposal Practices of Alaska Seafood Processors from the National Field Investigations Center, Denver, Colorado, and Region X, Seattle, Washington, Offices of the Environmental Protection Agency", published in December 1974. This study investigated 26 Alaska seafood plants and included bottom samples in the areas of many of the plants. This study pointed out the benificial effects that grinding and discharge into areas of adequate tidal flushing have on seafood discharge into marine waters.

Kenai

Page 22. The values in both tables 1 and 2 represent the total waste from each of the product commodities listed. However, it should be noted that much of this waste is in the form of blood and other liquids and, as such, does not represent recoverable waste or waste which would have an effect on the benthis community. It is estimated by industry sources that while waste from a canned salmon process may represent 35% of the live weight, only 20% of this live weight is what is termed "recoverable waste". For a fresh and frozen operation, depending upon whether or not the fish are dressed heads on or heads off, only 10 to 15% of the live weight is recoverable waste. It must be remembered that the non-recoverable wastes are not affected by grinding or screening as they are either liquid or particles too fine to be affected by the action of the equipment.

Cordova

Page 43. The problem noted at the St. Elias dock with the dumping of whole crab shells must be recognized as not typical of plants complying with the Requirements of their NPDS permits.

Page 47. Reference is made to a "fully loaded tender boat". This is redundant as the industry use of the term "tender" connotates a boat and, thus, the term "boat" is not necessary. Also, the term "set" which follows tender boat has a unique meaning within the fishing industry. A set is the term used to describe the setting of a fishing net during the seining process, and as such, the terms either the "tender sat on the line" or the "tender went dry on the on the line" instead of "set" should be substituted, unless the boat did actually release its net over the discharge pipe and this was the cause of the breakage.

Page 49. In reference to the North Pacific processors discharge pipe, the numberous fish tails and heads observed at the North Pacific processors discharge indicates that the grinder had not been working at this location for a considerable period of time. Had the grinder been working properly, the buildup might not have occurred.

Page 50. It should be noted that at several locations including the Morpac outfall there were very few flatfish. This compares markedly with the number of flatfish noted at the other plant discharges. It would appear that there is a difference as far as pelagic fish are concerned in the attractions by seafood waste depending upon the particle size and the manner in which it is discharged. We recognize that this study was limited to benthic organisms and we are familiar with the concerns over the fact that pelagic fish are migratory and do not necessarily prove that the environment is desirable. However, we do hope that the final report will note the presence of the pelagic fish and of starfish, crabs and sea anemone at the discharge sites from the seafood processing plants.

Page 51. It is noted that stations M, K and L had a very high incidence of empty mollusk shells and shell fragments, in some areas covering an estimated 50% of the area. The report does not make clear the area this actually represents and how large a portion

Page 7.

of the bottom was covered at each of the sites.

Page 54. An absence of waste debris at both NEFCO outfall sites was noted and it was suggested this was due to good flushing action. It is also very likely that this was due to proper operation of the grinder. Had the grinders been maintained at the two outfalls noted to have grinder problems, namely St. Elias and North Pacific Processors, it is very likely that no buildup would have occurred.

Pagd 54. The source of the higher water temperature is hard to determine. Normally, the seafood processing operation does not involve the introduction of much heat into the processing stream. In some processing plants, water is used to cool retorted cans. However, this would be an intermittant flow and would not cause a constant elevation of the discharge water temperature. It is more likely that the water source which raised the temperature was the Cordova City Municipal Water Collection System which discharges in the same general area. As this system handles domestic waste from the city as well as the processing plants, it is possible that the warmer water noted was from this source.

Page 83. The lack of sediment at both NEFCO sites, GT and N-O points out the importance of conducting a full cycle survey. It is unfortunate that SCS Engineering was unable to visit the plants prior to the beginning of the processing season to determine the amount of dissipation the waste experienced during the Fall, Winter and Spring of the year.

Pages 87, 88 and 89. The study demonstrates the necessity to maintain grinders in proper working order and the impact that unground seafood waste has on the ecosystem, as well as the need for the proper placement of the discharge pipes. Outfalls must be placed in an area receiving adequate tidal flushing to prevent the possibility of waste buildup. It should be noted that tidal flushing is peculiar for each location and is not necessarily indicated by a single, arbitrary depth.

General Comments on Methodology of Biological Assay

It is difficult to compare the results of the SCS study with those of the EPA group in Yaquina Bay and the University of Alaska group in Dutch Harbor due to the SCS use of a second screening of 0.5 mm mesh after the primary screening of 1.0 mm used. To maintain consistency, we would recommend that the agency used the 1.0 mm mesh screening results throughout its final report. It is also unfortunate that the Yaquina Bay study and the Alaska study utilized different methods for the determination of species density as well as different indices of species dominance. It is unclear how Simpson's Index of Dominance and the Bray-Curtis Dissimilarity Coefficient used in the Yaquina Bay study compare with the Shannon-Wiener formula and the Czekanowski Coefficient used by SCS. It is hoped that the agency will utilize a standard set of methods in analyzing the data.

Comments on Report Titled "An Investigation of Certain Aspects of Crab Processing Waste Disposal Practices: In Situ and In Vitro Responses of Vibrio Parahemoliticus and Vibrio Anguillarum", 1978.

This study is highly speculative in nature and is limited primarily to laboratory work. Its application to a study of the effects of seafood waste on receiving water is of limited value. The EPA in its Denver report already considered vibrio as a pollution indicator and in that document dismissed it as being of insignificant consequence. There were four major problems with the study as presented.

1. None of the samples from any of the locations investigated were positive for either Vibrio parahemoliticus or Vibrio anguillarum. A third vibrio species was discussed throughout most of the report but its relationship to the two organisms which were the subject of this report was never explained.

2. The study utilized crab meal rather than actual crab processing waste. Since the crab meal has already been broken down to a certain extent and has had other nutrients released, it can hardly be compared with actual crab shells. Growth on crab meal does not conclusively prove that an organism would be capable of growing on the actual waste.

3. The crab meal was sterilized prior to the innoculation with the organism to be tested; this eliminated any competitors. It must be remembered that there are numberous competitors present in the actual marine environment which would greatly affect the viability of any vibrio present.

Page 10.

4. Artificial, rather than natural, seawater was used in a number of the experiments. This artificial seawater did not have the natural competitors which would be present. This represents a problem similar to that encountered in sterilizing the crab meal.

Page 21. It must be noted that the minimum growth temperature for Vibrio parahemoliticus is above the water temperatures for Dutch Harbor noted in the report titled "Interim Report to the Environmental Protection Agency on the Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Water at Dutch Harbor, Alaska" by the University of Alaska, October 1, 1978. Conversation with Dr. John Liston of the University of Washington, a noted authority on Vibrio parahemoliticus, indicated that 15°C. is the minimum growth temperature for Vibrio parahemoliticus in situ.

Of all samples collected during the study, only one was positive for vibrio. This organism was found in the Cordova area and was classified as Vibrio alginolyticus. It was not a subject of the study and is not a human or fish pathogen. The relevance of the finding of this organism in a single sample is questionable.

There have been no cases of vibrio caused diseases reported for either the Dutch Harbor area or Codova. We hope that the Agency will recognize the limited applicability of this report to the Section 74 Seafood Study.

Comments on Report Titled "Interim Report to Environmental Protection Agency of the Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Water at Dutch Harbor, Alaska" by Howard M. Feder and David C. Burrell, Insititute of Marine Science, University of Alaska, October 1, 1978

As this is an unfinished interim report, the industry feels it cannot adequately comment on the material presented at this time. The indication of the impact of the waste on the benthic population appears to be the major item yet to be concluded and, without this material, comments would be premature. It is hoped that the agency will consider the additional new material presented with these comments titled "Biological and Water Quality Implications of Current Crab Processing Waste Disposal Practices in Dutch Harbor, Alaska", March 1979, by Dr. Timothy J. Bechtel and "Investigation of Crab Waste Disposal Alternatives in Dutch Harbor, Alaska" by Brown and Caldwell Consulting Engineers, March 1979, when evaluation the impact of seafood waste at the Dutch Harbor site.

Comments on Report Titled "Benthic Macrofauna, Sediment and Water Quality Near Seafood Cannery Outfalls in Yaquina Bay, Oregon, by Marine and Freshwater Ecology Branch, Corvallis Environmental Research Laboratory, Environmental Protection Agency, Marine Science Center, Newport, Oregon, January 29, 1979

The industry has only a few general comments on this study. For the most part, there appear to be no major problems caused by the seafood discharges in this area. The agency consistently uses the term "seafood cannery" for processing plants. Very few of the seafood processing facilities in Yaquina Bay are actually "canneries". Most of them, in fact, freeze the product. This same problem in terminology exists in the Dutch Harbor benthic study. The distinction is more than academic as there are differences in the waste generated by canneries compared to waste generated by freezing facilities. The Agency has recognized these differences in establishing different effluent guideline limitations for canning operations versus freezing operations.

Again it is noted that the indices of species diversification and dominance used in this study were different from those used in the SCS Engineering study.

creatures tending to live in open seas
rather than in waters near land.

As a final note, industry again hopes that the agency will note the presence of pelagic species and other marine life in the plant discharge areas which indicates that the discharges are an important part of the marine food web.

Additional Material

We wish to submit the following reports for consideration by the Agency. We believe that these reports have considerable bearing on the Section 74 Seafood Study.

"Ecological Changes in Outer Los Angeles - Long Beach Harbors Following Initiation of Secondary Waste Treatment and Cessation of Fish Cannery Waste Effluent" by Institue for Marine and Coast Studies, Allan Hancock Foundation, Los Angeles, California, April 1979.

"Biological and Water Quality Implications of Current Crab Processing Waste Disposal Practices in Dutch Harbor, Alaska" by Dr. Timothy J. Bechtel, March 1979.

"Investigation of Crab Waste Disposal Alternatives in Dutch Habor, Alaska" by Brown and Caldwell Consulting Engineers, March 1979.

ADDRESS ONLY THE DIRECTOR,
FISH AND WILDLIFE SERVICE

United States Department of the Interior

FISH AND WILDLIFE SERVICE
WASHINGTON, D.C. 20240

In Reply Refer To:
FWS/ES

AUG 31 1979

Mr. Robert B. Schaffer
Director
Effluent Guidelines Division
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Schaffer:

In response to your letter of May 23, 1979, as well as a meeting with Mr. Cal Dysinger of your staff on July 24, 1979, we are providing limited comments on your seafood study. We have reserved comments on the report by Ms. Dorthy Soule. We understand that staff from our Laguna Nigel Field Office will provide separate comments on this report. Our comments will be brief and limited to the Alaska and Oregon reports.

In general, we believe the reports received are based on short-term studies under conditions requiring an extremely fast turnaround time. Furthermore, the reports are limited in scope, appear to have significant oversights and omissions, and in most cases no provisions appear to be made for follow-up studies. These reports tend to make rather broad conclusions regarding environmental impacts which we believe are not in keeping with the character of the studies. An additional report by the National Marine Fisheries Service on Finger Bay in Alaska is enclosed for your information.

Specific Comments:

Under this heading brief comments regarding specific reports are provided.

1. An Investigation of Certain Aspects of Crab Processing Waste Disposal Practices: In Situ and In Vitro Responses of Vibrio parahemolitius and Vibrio anguillarium.

   This report by the University of Alaska is very specialized and limited in scope. It is an excellent investigation of the ability of two marine life intestinal pathogens of the genus Vibrio to survive in the marine environment near seafood processing wastes. However, the substance of the report does not justify its use as an evaluation of the potential for diseases of marine life related to the dumping of seafood processing wastes. Such wastes are ideal breeding grounds for large concentrations of fungi, molds, and other types of decomposers. Many organisms in these groups are well known to be opportunistic parasites which periodically infect marine and freshwater organisms on a large scale. Such groups should be thorougly investigated in any evaluation of seafood dumping sites.

2. Working Papers #EPA 910-8-77-100 and 910-8-78-101: "The Dutch Harbor Studies"

We fully concur with many of the conclusions of report #EPA 910-8-77-100 regarding Dutch Harbor. Seafood wastes are primarily responsible for the adverse conditions observed in Iliuliuk Harbor, inner Iliuliuk Bay, and Dutch Harbor. Investigations by ourselves and others support this conclusion. Referral to other studies of this type suggests that this report does not address the full impact of the discharges of seafood wastes in the bay area. For instance, there was no attempt to analyze for H_2S, a significant environmental by-product of the waste. Certainly the conclusions regarding the elimination of discharges from these areas are appropriate and well supported.

The investigation of the discharges to the west side of the island described in report #EPA 910-8-78-101 appears to be superficial and belie the full impacts which are apparently occurring along the west coast of the island. The fact that decomposition is considerably slower than the rate of addition by the discharges supports this belief. It is also supported by the fact that many of the active discharge pipes were moved during the study period creating adjacent pollution sites of close proximity. The fact that the abandoned sites have significant debris and are totally devoid of life after a period of a year or more would suggest a potential for significant damage near shore by such movement of the pipe. The failure of this report to quantitatively assess the amount of H_2S in these locations or determine the western (seaward) extent of the waste from the discharge pipes also limits the report's value as a tool for assessing impacts of the processing wastes.

3. Benthic Macrofauna, Sediment, and Water Quality Near Seafood Cannery Outfalls in Kenai and Cordova, Alaska.

We believe that the conclusions of the study are somewhat misleading. The report appears to minimize existing problems and fails to address the potential for future problems. Certainly the study at Cordova occurred during a season of minimum productivity and the study was not sufficiently in-depth to justify a solid conclusion that the impacts are of a highly localized nature. Follow-up studies are needed to verify the findings. Extensive sediment analysis should be incorporated in future studies including nutrient loading, H_2S production, and ammonia production. Trends in the ecosystem near the waste sites and down-current from them need to be ascertained before any firm conclusions can be drawn regarding impacts.

Similar weaknesses are found in the Kenai study. Our experts agree that no significant impacts may be demonstrated at Kenai at this time. However, they raise the question of potential significant impacts at Kenai with increased loading from additional plants. A similar argument can be made for the Cordova situation.

In the review of previous Alaskan studies section, there are several summaries which are misleading and in some cases invalid. For example, we cannot accept the analogy to Iliuliuk Bay presented in the summary of the Brickell and Goering studies. The fact that natural loading of dissolved organic nitrogen and ammonia in an estuary where salmon carcasses accumulated after spawning approximates the ammonia values in Iliuliuk Bay does not mean the two situations are truly comparable. A consideration of the total freshwater drainage area discharging into the estuary or bay versus the loading and other constraints of the two systems would be necessary before comparability could be contemplated.

The summary of the Nakatoni and Beyer mortality studies provides another example, since the studies are summarized without noting the fact that chronic exposure and secondary effects are not addressed.

The community analysis procedure discussed in the methodology could prejudice against any rare or endangered species found in the study area. Furthermore, we disagree with their contention on page 36 that using a 0.5 mm instead of a 1.0 mm screen changes the conditions described. The conditions are the same; the refinement of those conditions is what differs. The decision of whether or not to use more refinement is tied directly to comparability with techniques used in other studies. Without comparability, refinement is of no value.

4. Benthic Macrofauna, Sediment and Water Quality Near Seafood Cannery Outfall in Yaquina Bay, Oregon.

This report appears to be better done than the Alaskan reports, but still suffers from the same basic weaknesses. H_2S was not addressed. No effort was made to evaluate the relationship of carcinogenic benzopyrene effects to the presence of the seafood wastes, nor was there an effort to determine the source or other possible interrelationships of the benzopyrenes to seafood processing wastes.

Follow-up studies would be needed for the conclusions of this report to be concrete. In addition, loading evaluations of the marine system in Yaquina Bay should be conducted.

5. Section 74 Seafood Processing Study.

We agree with the report's observed differences between the Alaskan seafood industry and the industry found in the contiguous United States. Furthermore, we concur that the reluctance of other processors in the vicinity by the Alaskan fish meal plants to screen their wastes has contributed to the limited success of the enterprises. The report's observation that allowing plants to continue grinding waste for discharge to the marine environment does not provide the necessary incentive for effective in-plant water and waste management practices is well taken.

The report only addresses the problem of waste reduction processes. We believe that the potential value and feasibility of waste disposal technology should also be addressed by EPA, but have no indication that it has been seriously addressed in connection with this series of reports. One possible disposal technology that might be explored is the use of the collection system in reverse to spread the waste over a large area of ocean to create a more natural situation for its degradation and eliminate its adverse impact.

We trust these comments will be helpful to you in preparing your final report. Since we realize that these reports are mandated by Congress and provide the potential basis for future decisions, we have emphasized their limitations and oversights and how they might affect any conclusions of negative impacts. If there are any additional questions, please contact my staff for clarification.

Sincerely yours,

M J Spear

Michael J. Spear
Associate Director

Enclosure

STATE OF ALASKA
DEPT. OF ENVIRONMENTAL CONSERVATION

JAY S. HAMMOND, GOVERNOR
POUCH O – JUNEAU 99811

RECEIVED
JUN 29 1979
ENFORCEMENT DIVISION
REGION 10

June 20, 1979

XHoo 790702
XJaKa 790702

Mr. Denton Sherry
President
Whitney-Fidalgo Seafood, Inc.
Box C 99308
Seattle, Washington 98199

Dear Mr. Sherry:

This letter is in response to your letter to me dated June 6, 1979. We appreciate your taking time to set forth your views on seafood waste disposal regulations in Alaska. Increased dialogue between the Industry and this Department would be beneficial to all concerned parties.

As you are probably aware, we have advocated dropping the distinction between "remote" and "non-remote" sites for the purpose of seafood waste disposal. It is our belief that screening of seafood wastes should not be arbitrarily mandated, but rather should be invoked where receiving water conditions require it. For example, I'm sure that almost everyone would agree that the processors around the community of Kodiak need to be screening their seafood wastes.

Our position on screening has unfortunately been made difficult by some of the seafood processors in the "non-remote" communities not adequately disposing of their wastes. Improper disposal includes such practices as 1) dumping wastes including fish heads and whole carcasses in large piles under docks, 2) inadequate outfalls for the waste that is ground and 3) inadequate attention to reducing floating solids and foam. Efforts by the entire industry to run as clean an operation as possible would go a long way to strengthen the industry's position on adequate disposal practices. Toward that end, we plan to check on industry progress this summer in Petersburg and Ketchikan.

As you point out, the Dutch Harbor crab waste situation is a vexing problem. Most of the processors are to be commended for the measures that they have taken to clean up the waters of Illiuliuk Harbor. This leaves us all with the problem of rapidly accumulating wastes from the discharges to the west side of Amaknak Island. As noted in the recent Bechtel report, prepared at the processors' behest, the piles do last through the winter. A University of Alaska study shows detrimental effects on the benthic environment occurring 0.3 mile away from the outfalls. Accordingly, we can not fully agree with your contention that the crab waste problems are minimal and localized.

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Hopefully, the current shallow water discharge study being conducted by the processors will result in answers that will help alleviate some of the existing problems with seafood waste accumulation. It would appear that the processors should not depend exclusively upon this solution. The same large volume of waste is still being discharged in essentially the same small area. The processors should continue to explore alternative disposal options. We are in concurrence with the processors' contentions that physical constraints in the Dutch Harbor area (including weather) will make barging difficult at certain times of the year. Perhaps barging the majority of the wastes while allowing grinding and discharge during foul weather would be a workable solution.

In conclusion, everyone's best efforts to resolve the existing problems should result in viable solutions amenable to all. Please let me know if I can be of further assistance.

Sincerely,

C. Deming Cowles
Deputy Commissioner

cc: Roger De Camp
Lloyd Reed

bcc: Kyle Cherry
Deena Henkins
Mark Brodersen
Ron Hansen

PACIFIC SEAFOOD PROCESSORS ASSOCIATION
1600 South Jackson Street
Seattle, Washington 98144
(206) 323-3540

August 17, 1979

Mr. Calvin Dysinger
Effluent Guidelines Division (WH-552)
U. S. Environmental Protection Agency
Washington, D.C. 20460

Dear Cal:

The University of Alaska final report titled "Impact of Seafood Cannery Waste on the Benthic Biota and Adjacent Water at Dutch Harbor, April 1, 1979", has been reviewed by a number of our members.

This report contains some well documented, valuable information on conditions at specific sites throughout the Dutch Harbor area. This information will be very helpful as a small part in understanding the entire question of the condition at Dutch Harbor. However, this report falls far short of defining the impact of seafood waste on the area as its title implies.

The fact that the report has expanded from 73 pages in its interim form to 211 pages in its final form, without any additional site studies, is a symptom of the problem. From the beginning, we have stated that investigations for the Section 74 Seafood Study should cover a sufficient period of time to determine the changing conditions and effects in an area during the season. While we understand the money and time problems in this type of approach, the same question keeps reoccuring. That is, what is the real impact of the discharge of seafood waste on the environment? A study such as this which lasted only 2 days cannot adequately describe the present situation, let alone the estimation of effects in the future. This is like trying to draw a curve from a single data point which itself is based on an insufficient sampling. The lack of sufficient data to fully define the impact is demonstrated in this report by the numerous suppositions and estimates throughout the text. The terms "expected to", "may", "probable" and "potential danger" are prevalent. The authors themselves recommend that additional studies be conducted to put the situation in proper perspective.

There are other problems with this report which tend to cloud the main issures. Areas which receive considerable attention such as the inner harbor, the outer harbor, Captain's Bay and Scan Bay, while of academic interest, have nothing to do with the impact of the discharge of processing waste. All processing waste is discharged on the north or west side of Amaknak Island in Unalaska Bay. Lengthy discussions of sills, currents and natural anoxic conditions in areas not receiving processing waste do not meet the goal of this study. Even worse, they set the tone of the report and tend to lead the reader toward the unsupported conclusion that seafood processing waste is dangerous to the environment. In further support of our objections, water column sulfide was detected at only one station, but we were led to believe the situation was much more serious. Grab samples from the piles should have a sulfide odor as this is a normal and expected result of decomposition. The report states that negative effects of the waste piles dissipate within a relatively short distance and that processing is not impacting broad areas near the outfalls. Then, rather than relating the small size of the affected areas to the large size of Unalaska Bay and determining why there is no broad impact, the authors jump to the unsupported position that accumulated wastes will eventually cover much of the nearshore bottom and cause serious ecological and sanitary problems unless the discharge of waste solids is prohibited.

In summary, we feel that the report is inconclusive and does not evaluate the impact of the direct discharge of seafood processing waste. It leaves unanswered the question of why years of direct discharge have evidently only slightly affected the environment. We are dissapointed that so much effort has been expended without answering the basic question.

In order to determine the mechanics of direct discharge and its effects on the environment, the Dutch Harbor Processors are presently conducting a research project. Our earliest concerns have been with the fate of the discharged waste over an extended period of time. History itself has disproven the theory that the waste piles grow progressively larger without significant dispersion. The enclosed July 1979 Status Report on the processor's project indicates that there is considerable dispersion under certain conditions over a period of time. This project should provide us with answers to some of the questions raised when Congress mandated the Section 74 Seafood Study. We appreciate the opportunity to comment on the University of Alaska study and are looking forward to seeing the Section 74 Study draft.

Very truly yours,

Roger A DeCamp

Roger A. DeCamp
Director, Technical Services

RAD:vcb
Enclosure

NEARSHORE DISCHARGE EXPERIMENT
STATUS REPORT
JULY, 1979

General

The Vita Foods test outfall is located on the west side of Amaknak Island and serves the Barge Vita and one additional floating vessel on a seasonal basis. The outfall discharges ground crab waste through an open-ended pipe, positioned eight feet off the bottom in 18 feet of water (MLLW). Distance to shore is about 110 feet. Discharge through the test outfall began on March 29, 1979.

Results through 1979 Tanner Crab Season

Production and Waste Discharged. Over the period March 29, 1979 through June 11, 1979, Vita Foods processed 4.1 million pounds of raw crab and 188,000 pounds of shrimp. Assuming a waste solids/raw crab ratio of 25 percent,[1] total waste generated is approximately one million pounds. At 50 pounds crab waste solids per cubic foot (Bechtel, 1979), this represents approximately 20,000 cubic feet of crab waste solids. If a recovery rate of 15 percent is applied to the 188,000 pounds of shrimp processed (Tondre, 1979), approximately 160,000 pounds of shrimp waste were discharged.

Waste Pile Observations. The attached table shows the results of diver observations at the test discharge site. Over the tanner crab season, the pile grew in size until late May, when it reached 10,000 cubic feet. June 11 observations show an increase in pile size of over 7,000 cubic feet, while only 3,000 cubic feet of crab waste was discharged since the prior dive. The difference is attributed to the shrimp processed during the same period. Shrimp waste settles poorly, resting as a floc-like blanket on the bottom. Pile measurement is very difficult under these conditions.

The subsequent dive on July 9, 1979, when shrimp was not being processed, showed measured pile volume had declined by nearly 10,000 cubic feet, a greater reduction than might have been expected to occur had the pile consisted of crab waste alone. Neglecting anomalous June 11 results, maximum pile volume was 10,080 cubic feet, approximately 57 percent of the amount of waste solids discharged. Maximum area covered was 4,240 square feet ~~in~~ late May (again neglecting June 11 figures). Diver reports indicate that the waste pile remained cone-shaped throughout the season with maximum depth ranging from seven to nine feet.

---

[1] The principal species processed was C. opilio, which has a waste/solids ratio slightly higher than the 20 percent reported by Bray (1978) for C. bairdi.

Through the entire tanner crab season no onshore accumulations of crab shell were observed. While some lateral pile movement was observed, particularly with lighter shrimp shell, pile contours did not show pronounced net drift, nor was any significant downslope movement indicated. At no time during the season did waste accumulations exceed applicable permit requirements for bottom coverage.

Weather. The spring and summer in Dutch Harbor have been unusually mild with no sustained storms of significance. Over the period March 29 to June 11, winds exceeding 20 knots were recorded on only nine occasions. The wave environment in the vicinity of the test outfall has been similarly mild.

Discussion

The experimental nearshore discharge has now been operational for four months. In the planning stage, the processors assumed that this experiment would continue for a relatively longer period than four months, and that the effects of good and bad weather, winter and summer and new and mature piles would be observed and evaluated. The experiment continues to comply with Environmental Protection Agency conditions that no shore accumulation occur and that pile size does not become excessive. It would be premature to attach major significance to preliminary results (e.g., pile buildup and decay, the lack of beach accumulations, compliance with the existing permit requirements for bottom coverage). If the experiment is to produce meaningful results, either positive or negative, it is important that the duration of the test be sufficiently long to account for unusual discharge conditions. Consequently, it is desirable that the nearshore discharge experiment continue.

Vita Foods Test Outfall Waste Pile Volume Changes: 1979 Tanner Crab Season

Date	Pounds raw crab processed to date	Waste crab solids discharged to date, cu ft	Pile volume, cu ft	Change in volume, cu ft	Area covered, sq ft[a]	Maximum pile depth, ft
3/29	0	0	0	--	0	0
4/5	342,662	1,713	1,003	+1,003	480(3)	8
4/14	763,528	3,818	4,598	+3,595	2,000(3)	9
4/27	1,663,747	8,319	5,656	+1,058	2,960(2)	7
5/11	2,548,311	12,742	8,366	+2,710	3,310(1)	9
5/26	3,548,395	17,742	10,080	+1,714	4,240(1)	7-1/2
6/11[b]	4,188,868[c]	20,944[d]	17,295	+7,215	10,950(1)	8-1/2
7/9	4,188,868	20,944	7,502	-9,793	3,080(4)	8

[a] Area covered to depth, in inches, indicated in parentheses.

[b] End of Tanner Crab processing.

[c] Does not include 188,277 pounds of shrimp processed.

[d] Does not include 160,000 pounds of shrimp waste.

BIOLOGICAL AND WATER QUALITY IMPLICATIONS OF CURRENT CRAB PROCESSING WASTE DISPOSAL PRACTICES IN DUTCH HARBOR, ALASKA

PACIFIC SEAFOOD PROCESSORS ASSOCIATION
SEATTLE, WASHINGTON

March 1979

Timothy J. Bechtel, Ph. D.
Consulting Biologist

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ACKNOWLEDGEMENTS

This study could not have been accomplished without the excellent cooperation received from the Dutch Harbor crab processors. The assistance of the Steering Committee, consisting of Roger DeCamp, Pacific Seafood Processors Association; Dick Pace, Universal Seafoods, Ltd.; and Ken Moll, Castle & Cooke, Inc., is greatly appreciated. Data requests and information concerning processing activities were expeditiously handled by Rich White and Bill Tondre, Universal Seafoods, Inc.; Terry Bertoson and Doug Weaver, Sea-Alaska Products, Inc.; Jack Showalter, Pan-Alaska Fisheries, Inc.; Lance Van Brocklin and Paul Palmer, Whitney-Fidalgo Seafoods, Inc.; and Arne Abrams, Pacific Pearl Seafoods.

The assistance of Steve Bingham and Tony Harber, Brown and Caldwell Consulting Engineers, was particularly appreciated. Duane Karna, EPA Region X; Bob Nelson, Alaska Department of Fish and Game, Dutch Harbor; and Howard Feder, Institute of Marine Science, University of Alaska, provided valuable insight to the biological characteristics of the study area and effects of crab wastes. Finally, I would like to thank Marty and Paul McCasland, Dutch Harbor Divers, for their persistent diving efforts, particularly during less than desirable weather conditions.

CONCLUSIONS

1. Waste pile compaction and slumping, microbial degradation, downslope movement, and dispersion are four mechanisms affecting the fate of ground crab wastes discharged in nearshore areas around Amaknak Island. At the Pacific Pearl and Universal outfall locations, compaction, microbial degradation, and downslope movement appear to be the dominant factors. The majority of wastes discharged at the shallow Vita outfall are dispersed by wave action with some degradation and downslope movement occurring. Pan-Alaska and Whitney-Fidalgo pile volumes are also reduced by compaction, degradation, and downslope movement, but some dispersion by wave action or wave-induced bottom currents is also indicated. All wastes discharged through outfalls at depths ranging from 20 to 50 feet off the spit separating Dutch Harbor from Iliuliuk Bay were almost completely dispersed by wave and tidal currents under winter conditions. Only a small waste pile was observed at the Sea-Alaska outfall in early January.

2. The waters adjacent to the Dutch Harbor - Iliuliuk Bay spit have a great capacity for waste dispersion. Essentially all of 91,700 cubic feet (4,585,000 pounds) of ground crab wastes discharged through three outfalls during the 1978 king crab season were effectively dispersed east of Amaknak Island over a 112-day period for an average rate of 819 cubic feet or 0.89 percent per day. Seasonal effects on waste dispersion are pronounced in this area since only 5,231 cubic feet or 261,550 pounds of waste in the Sea-Alaska pile were dispersed and degraded over the three summer months of 1978 for an average rate of 58 cubic feet or 0.5 percent per day.

3. Whitney-Fidalgo did not process after their waste pile was measured on October 29. From then until January 3 the pile volume decreased by 12,146 cubic feet for an average rate of 184 cubic feet or 0.43 percent per day. Vita and Pan-Alaska continued to process crab through the January pile measurement dates, but since there was a net reduction in pile volumes, a net reduction rate could be estimated. Between October 29 and January 7 (70 days) the Vita pile was reduced at an average rate of 401 cubic feet or 1.1 percent per day, while the Pan-Alaska pile decreased at 235 cubic feet or 0.43 percent per day over a 67-day period. Based on these estimates, it appears that a shallow water discharge on the west side of Amaknak Island will provide effective dispersion at least during the winter.

4. Review of crab production data from 1975 through 1978 revealed that the amount of live crab purchased and the amount of waste produced have increased steadily. However, the percent of total and solid

waste produced per pound of live crab has been steadily declining because of decreases in meat production and increases in section production. The consequence of these production changes is that 41 percent less solid waste is discharged per pound of live crab processed.

5. Burrowing and attached marine benthic organisms are completely eliminated from areas that become covered with crab wastes deeper than about an inch. The wastes appear to have a smothering effect on these organisms and do not provide a suitable substrate for recolonization after deposition. Mobile bottom and swimming organisms are attracted to the piles, particularly those containing fresh wastes. The soft-tissue component of the waste provides a food source for these animals. There are no data to evaluate whether the species diversity and relative abundance of the fish and macroinvertebrates or any significant nursery areas have been affected by the wastes.

6. The seaward edges of the waste piles on the west side of Amaknak Island were observed to be moving downslope into deeper water. The University of Alaska's benthic study indicated that these wastes were completely degraded to an organic sediment within 0.3 mile of the shoreline. These results also indicated that complete degradation of crab waste can occur within several years. This study concluded that the waste piles caused total mortality of sediment-dwelling organisms but that these negative effects were dissipated over relatively short distances from the accumulated deposits. Degraded wastes provided an adequate substrate for benthic organisms in contrast to the partially degraded wastes further inshore and in the piles.

7. The amount of bottom area covered by the main waste piles varies during the year as the piles increase and decrease in size. The maximum extent of bottom coverage by the main piles totaled at least 126,000 square feet (3 acres) of the nearshore zone on the west side of Amaknak Island. For those wastes moving downslope, an additional 29 acres of bottom area can be assumed to be affected. The total bottom area of Unalaska Bay south of Hog Island is about 3.5 miles square or 2,240 acres. Thus, at present, crab wastes directly affect approximately 1.4 percent of the benthic environment.

8. Water quality data collected in October 1976, October 1977, March 1978, and June 1978 indicated that dissolved oxygen levels were always greater than 8 mg/l. The majority of samples indicated dissolved oxygen concentrations were greater than 10 mg/l in bottom water just offshore from the piles on the west side of Amaknak Island. Detectable levels of sulfide within a few feet of the piles, slightly elevated NH_3 concentrations in the overlying waters, and increased turbidity around the piles were the only water quality effects that could be associated with the crab waste discharges. Large amounts of sulfide are generated by the decomposing wastes, but the waters are highly oxygenated and have good mixing so that

the sulfide is rapidly oxidized or dispersed. Toxic concentrations of hydrogen sulfide may diffuse from the waste piles but the diffusion rate is orders of magnitude slower than the dispersion rate of overlying waters.

9. Observations of marine life around the waste piles indicate that there are not consistent toxic sulfide conditions existing. It appears that the surface of the waste pile remains aerobic, but that the interior portions of the pile are anaerobic. Colonization of the pile by marine organisms has not been observed because the shell particles do not provide a suitable substrate for organisms other than those affecting decay.

10. Evaluation of the screening and barging alternative indicates that deepwater disposal does not provide any substantial water quality and marine biological benefits compared to current waste disposal practices. In fact, there may be some disadvantages with respect to a slower degradation process and a greater amount of bottom area covered with crab wastes.

INTRODUCTION

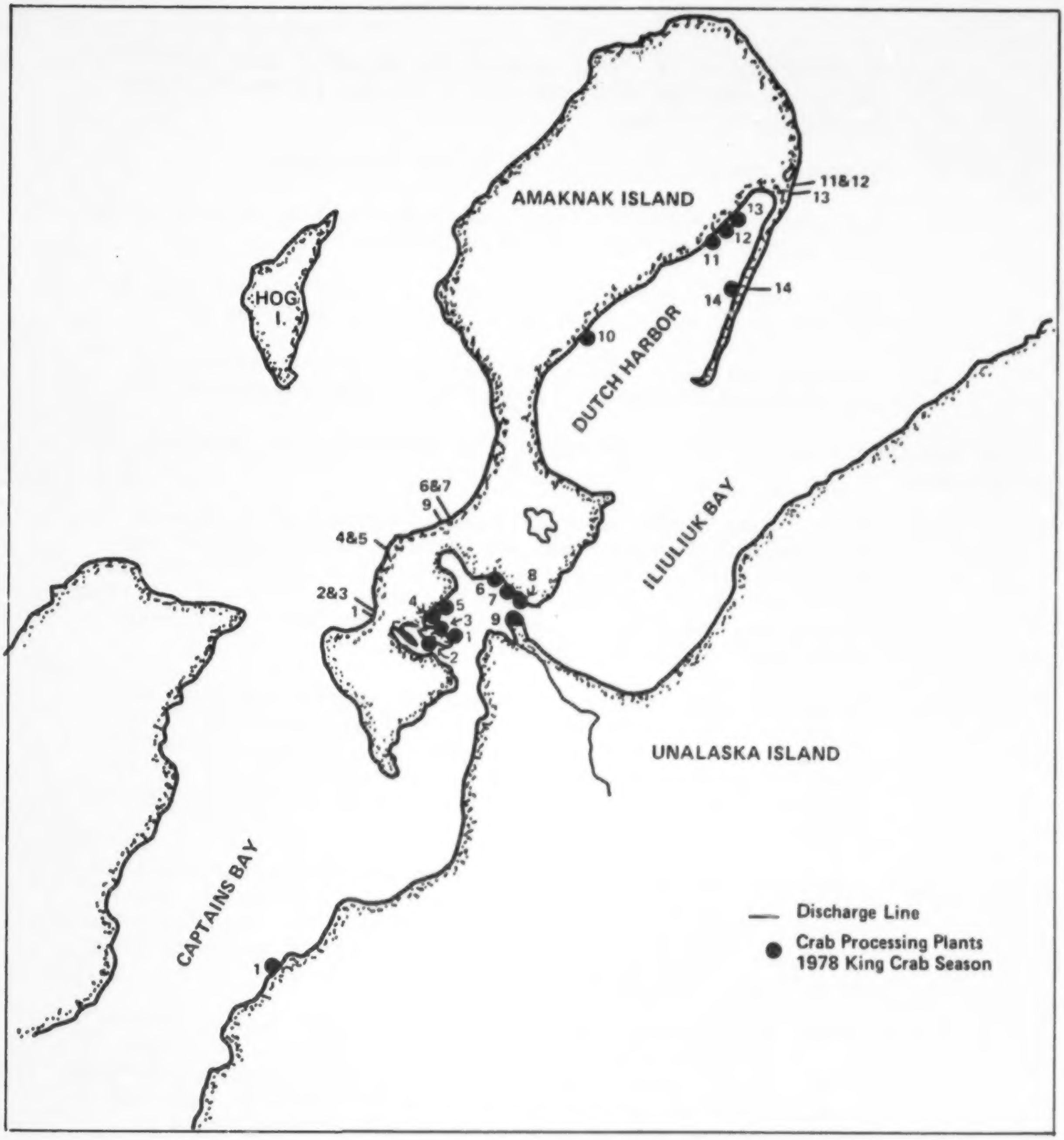
Dutch Harbor, Alaska, is a major center for processing Alaskan red king crab (*Paralithodes camtschatica*), blue king crab (*P. platypus*), and tanner crab (*Chionoecetes bairdi*). During the 1978 king crab season eight companies in Dutch Harbor processed approximately 60 million pounds of crab in three shore plants, two operated by Pacific Pearl Seafoods and one by Pan-Alaska Fisheries, and on twelve vessels from July through December (Figure 1). In addition, approximately 50 million pounds of tanner crab were processed from February through June 1978.

All processors attempt to grind wastes generated during processing to approximately 0.5 inch in diameter. At all but three of the facilities, ground wastes are transported from the confined harbor areas where the processors are located through pipes to discharge points in relatively unconfined nearshore areas. One facility discharges into Captain Bay, one into Dutch Harbor, and one screens ground wastes for disposal by barge at a deepwater disposal site northeast of Amaknak Island. Eight separate pipes discharge the large majority of the wastes into the nearshore waters on the east and west sides of Amaknak Island (Figure 1).

The Environmental Protection Agency has claimed that the nearshore discharge of processing wastes is unacceptable because of accumulations of waste on the bottom in the vicinity of the discharges. Current waste discharge permits issued by EPA require that all processors install screens to separate waste water from waste solids and barge the solids to deepwater disposal sites or otherwise dispose of them.

Although acknowledging that the accumulation of wastes in the nearshore areas has some localized environmental effects, the crab processors have argued that screening and barging as well as other alternatives such as production of by-products from the solids are impractical and uneconomical. In addition, all of the alternatives to the present disposal method suffer environmental and energy conservation disadvantages of their own. Finally, the processors contend that the extent of environmental degradation created by the accumulated waste has not been adequately defined nor has the problem been evaluated from the perspective of the overall effects on the nearshore marine ecosystem of Unalaska and Iliuliuk Bays. The key objectives of this study are to estimate more precisely the long-term environmental impacts of the current nearshore waste discharges and to compare them with the potential marine impacts of alternative disposal methods.

As part of an overall evaluation of current waste disposal practices and alternatives, the specific objectives of this study were to:


AMAKNAK ISLAND
HOG I.
DUTCH HARBOR
ILIULIUK BAY
UNALASKA ISLAND
CAPTAINS BAY
11&12
13
14
10
6&7
9
4&5
2&3
1
2
3
4
5
6
7
8
9
11
12
13
14
1
Discharge Line
Crab Processing Plants
1978 King Crab Season

1 PACIFIC PEARL (2)
2 GALAXY
3 UNISEA
4 VICEROY
5 VITA
6 WHITNEY
7 MOKA HANA
8 EASTPOINT
9 PAN-ALASKA
10 THERESA LEE
11 SEA ALASKA
12 SEA PRODUCER
13 ROBERT E. RESOFF
14 YARDARM KNOT

Figure 1

LOCATION OF CRAB PROCESSORS AND WASTE DISPOSAL SITES

1. Describe the relationship between the amount of crab waste discharged during the 1978 crab season and any subsequent change in waste pile volumes;

2. Estimate the dissipation rates of the waste piles;

3. Evaluate the marine biological and water quality effects of the crab wastes as currently being discharged;

4. Examine recent crab production data to identify any trends in the amount of total and solid wastes being produced; and

5. Evaluate the marine biological and water quality effects of any alternative disposal systems that might be proposed.

To achieve the objectives of the study, the following tasks were accomplished.

1. Dutch Harbor Divers were contacted to measure waste piles at the combined discharge location of Dutch Harbor Seafoods and Universal Seafoods and at the location of discharges from Pacific Pearl Seafoods, Vita Food Products (owned by Universal), Whitney-Fidalgo Seafoods, Pan-Alaska Fisheries, and Sea-Alaska Products three times during the 1978 king crab season.

2. Production data from each of the participating companies were obtained to calculate the volumes of waste discharged during the intervals between pile measurements. Net waste pile dissipation rates were calculated for those piles having smaller volumes after the end of the processing season than during the season.

3. Underwater photographs were taken of the Pacific Pearl and Pan-Alaska waste piles by John D. Showalter, Director, Quality Control, Pan-Alaska Fisheries, on September 11. He also photographed marine life present in the vicinity of the waste piles as well as that attached to the discharge pipes.

4. Previous crab waste, oceanographic, and water quality studies in the vicinity of Dutch Harbor were reviewed for pertinent information. Reports written by divers after routine discharge pipe inspections or when measuring waste depths 98 feet from the end of the pipe in accordance with discharge permit requirements were also reviewed.

5. Recent production data were obtained from those companies participating in this study and compiled to identify product trends and consequent changes in the amount of wastes discharged.

6. A close working relationship with Stephen H. Bingham and Anthony F. Harber, Brown and Caldwell Consulting Engineers, was maintained as they formulated and evaluated alternative waste disposal concepts.

MATERIALS AND METHODS

FIELD ACTIVITIES

Underwater Photographs. Photographs of the Pacific Pearl and Pan-Alaska waste piles using Ektachrome ASA 400 slide film were taken on September 11, 1978, with a Nikonos III camera and a Vivitar 283 flash with an Ikelite flash housing.

Pile Volume Measurements. At each waste pile the diver measured the depth of the pile at the end of the discharge pipe with a 10-foot graduated metal rod, measured distances to the perimeter of the pile in four directions with a graduated line, and then obtained intermediate waste depths with the rod between the top and perimeter of the pile. Periodic water depth measurements were made by the diver using a Dacor depth gage. Any marine organisms observed during the dive were noted. After each dive a scaled drawing of the pile was made showing waste depth contours.

REVIEW OF PREVIOUS STUDIES

During the last four years several EPA- and industry-sponsored studies were conducted to:

1. Document the accumulation of processed crab wastes in the discharge areas and to assess their localized effects on marine organisms and water quality (Stewart and Tangarone 1977; Karna 1978);

2. Investigate physical oceanographic and water quality conditions to determine the optimal location for discharges and to evaluate alternative outfall/diffuser systems (Colonell and Reeburgh 1978; Brown and Caldwell 1978);

3. Determine the amounts and characteristics of crab wastes and evaluate the economics of alternative utilization and disposal systems (Bray 1978); and

4. Document the effects of crab wastes on benthic infaunal invertebrates and water quality adjacent to waste disposal locations and throughout Unalaska and Iliuliuk Bays (Feder and Burrell 1978).

Pertinent data from these studies are utilized in the discussion section of this report.

DATA REDUCTION

Pile Volume Calculations. Pile volumes were calculated by using an Ott compensating planimeter to measure the total bottom area covered by the pile and the area of each successive waste pile depth contour from the perimeter to the top of the pile. The volume of each contoured section was obtained by multiplying the area of that section by its relative depth. The total pile volume was then determined by summing all the section volumes.

Discharged Waste Volume Calculations. For direct comparison with the waste pile volumes, the volume of waste discharged through each outfall between successive pile measurements was required. The production data supplied by each processor, i.e., pounds of live crab purchased and pounds of products produced, were used to calculate the total amount of waste produced. Using figures developed by Bray (1978), the total waste figures were reduced by 20 percent to account for fluids lost during butchering and cooking to obtain an estimate of the pounds of solid waste, i.e., shell, gills, and viscera, discharged. To convert the solid waste mass discharged to a volume of material on the bottom, a factor of 50 pounds of ground crab shell per cubic foot of waste was applied. This figure was presented by Bray (1978) and can be deduced considering the following factors. Brown and Caldwell (1978) found the density of crab shell to range from 1.15 to 1.20 while the density of crab meat was between 1.03 and 1.06. The density of seawater characteristic of Dutch Harbor is approximately 1.027 or 64 pounds per cubic foot. Using a density of 1.15, a cubic foot of crab shell would weigh 73.6 pounds if dry and tightly compacted.

Based on diver observations and photographs, the ground shell is not tightly compacted upon discharge, but rather forms an easily disturbed pile with a great amount of interstitial water. Consequently, less waste would be expected to occupy a cubic foot and allows the use of a lower weight-to-volume conversion factor than would be expected if the material were deposited on land. Based on this information, the 50 pounds per cubic foot conversion factor appears reasonable. In addition, processors at Kodiak Island use a rule of thumb of 50 pounds per cubic foot for king and tanner crab processing wastes delivered to a crab meal plant.

RESULTS AND DISCUSSION

UNDERWATER PHOTOGRAPHS AND DIVER OBSERVATIONS

Several photographs of the Pacific Pearl and Pan-Alaska waste disposal areas are presented here to depict conditions existing in the vicinity of the waste piles. All photographs taken on these dives are available for review at the offices of the Pacific Seafood Processors Association.

Pacific Pearl processed 1.8 million pounds of king crab during the summer and was discharging wastes when the photographs were taken, so that the wastes observed were fresh. On the other hand, Pan-Alaska had not operated since the tanner crab season ended in June, so that wastes observed had been decomposing for approximately three months.

Figures 2 through 5 are photographs of the Pacific Pearl pile. Figure 2 was taken at the edge of the waste pile looking toward the top. The waste is fresh and readily distinguishable as ground crab shells. Figure 3 is of juvenile baitfish feeding on waste particles floating above the top of the pile. These particles are most likely the soft crab tissues which are almost neutrally buoyant (Brown and Caldwell 1978). Figure 4 shows a flatfish at the edge of the pile. The discharge pipe can be seen in the upper left-hand corner. Note that the rocks adjacent to the pile and the visible section of the pipe are devoid of attached organisms. The Universal discharge line crosses over the Pacific Pearl pile. Figure 5 provides an indication of the density of attached organisms on the Universal line. The Pacific Pearl wastes below the line are visible in the lower right-hand corner. Significant numbers of lighter waste particles are prevalent in the water column. It appears that attached organisms can remain on the pipe even if it is close to the waste pile as long as the organisms are not covered by the waste.

Conditions characteristic of the Pan-Alaska discharge line and waste pile a few days before processing began are presented in Figures 6 through 9. Figure 6 shows attached organisms as well as mobile starfish and crabs on the pipe 90 feet from the outfall. Empty clam shells were prevalent in this area. The shoreward edge of the waste pile at this time was 45 feet further down the pipe. Figure 7 shows the mud-sand bottom characteristic of the area adjacent to the discharge line 5 feet from the shoreward edge of the pile. The pipe can be seen in the upper right-hand corner. Many small tanner crabs were present in this area. Figure 8 was taken at the shoreward edge of the pile where the discharge line enters the pile. Note that the pipe at this point is devoid of attached organisms, indicating that wastes previously covered it. Figure 9 is a closeup of the waste pile. In contrast to the Pacific Pearl waste pile (Figure 2),

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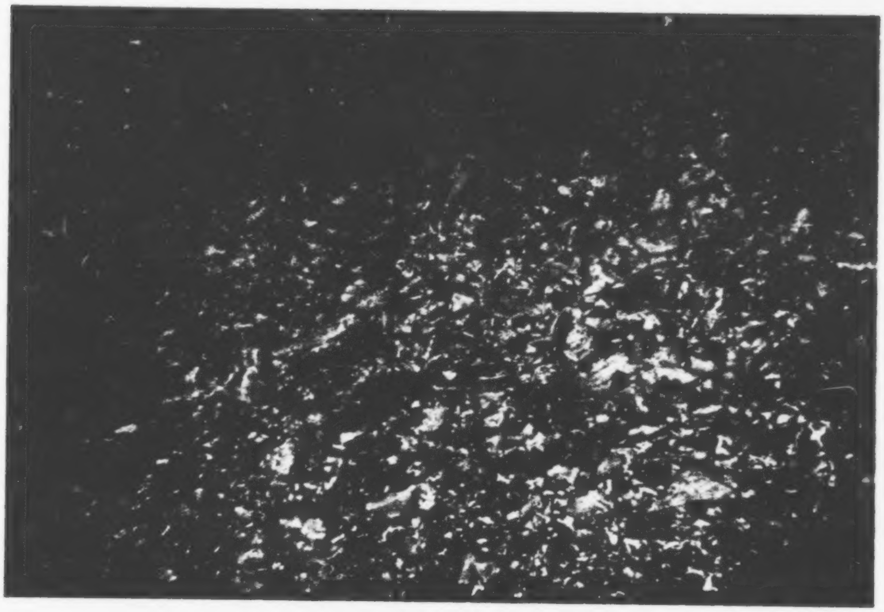

Figure 2. FRESH CRAB WASTE ON PACIFIC PEARL WASTE PILE LOOKING FROM EDGE OF PILE TOWARD TOP

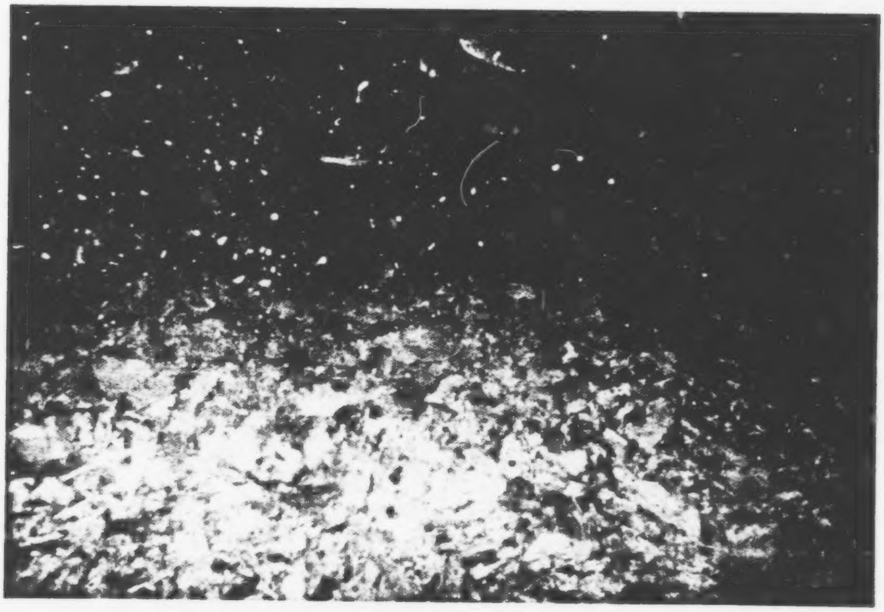

Figure 3. JUVENILE BAITFISH FEEDING ON WASTE PARTICLES FLOATING ABOVE THE TOP OF THE PACIFIC PEARL PILE

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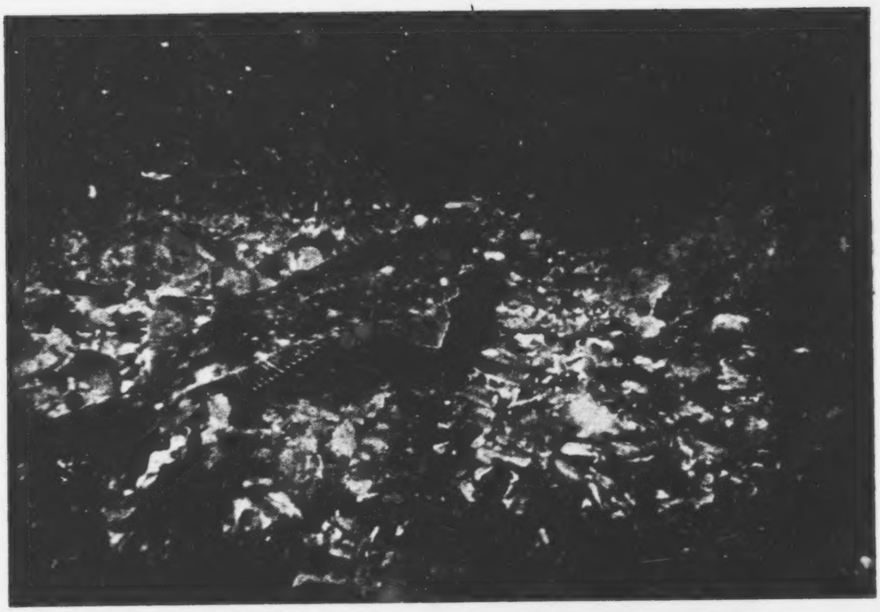

Figure 4. FLATFISH AT EDGE OF PACIFIC PEARL PILE

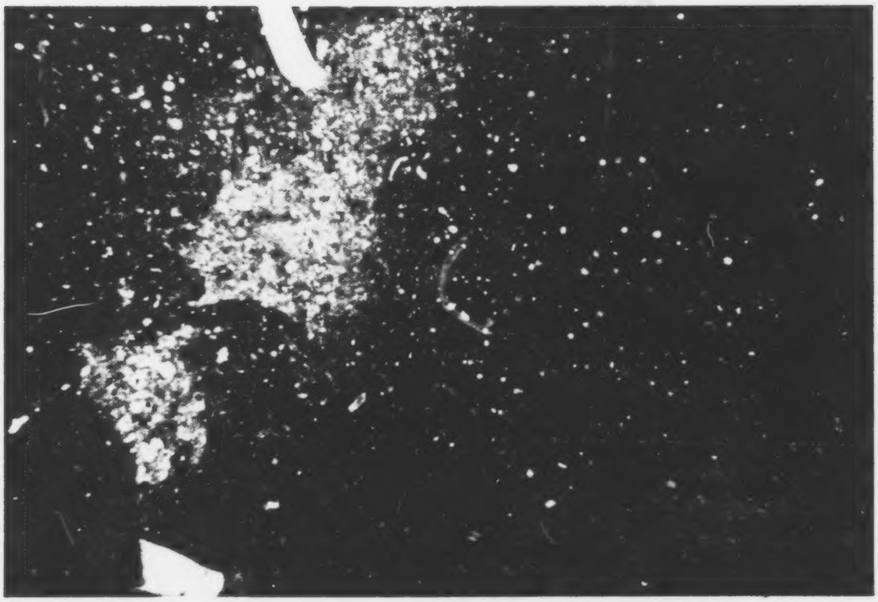

Figure 5. ATTACHED ORGANISMS ON THE UNIVERSAL DISCHARGE PIPE WHERE IT CROSSES OVER PACIFIC PEARL PILE

Reproduced from best available copy.

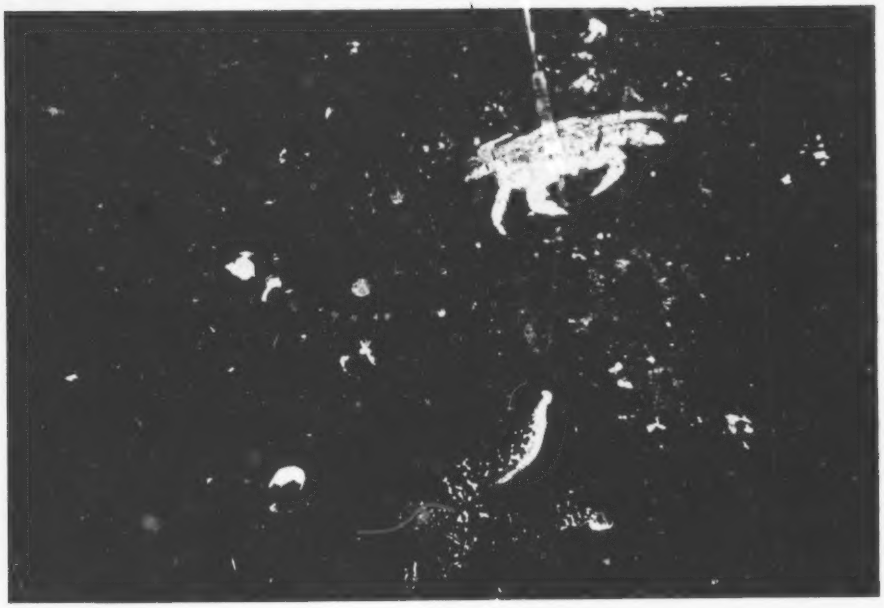

Figure 6. ORGANISMS ON PAN-ALASKA DISCHARGE PIPE 90 FEET FROM OUTFALL

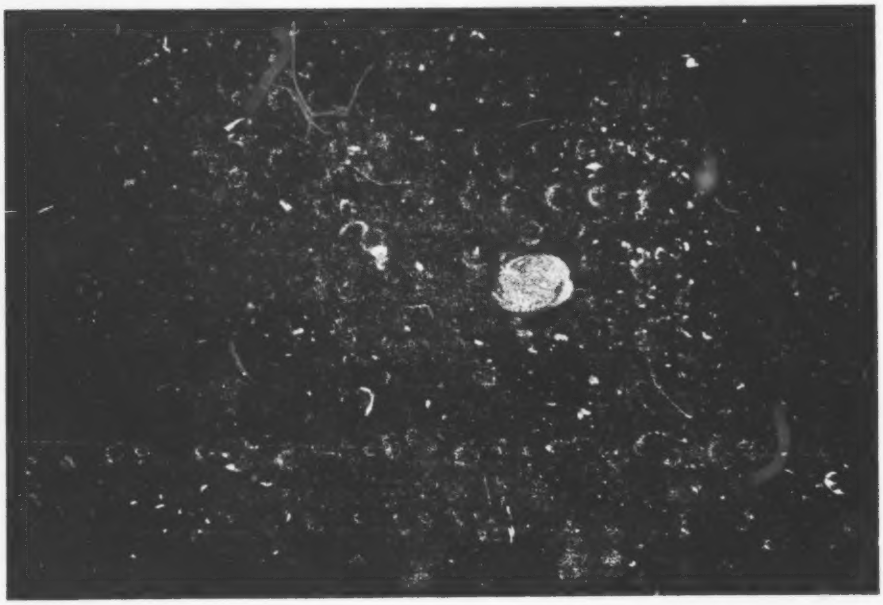

Figure 7. MUD-SAND BOTTOM ADJACENT TO PAN-ALASKA DISCHARGE PIPE

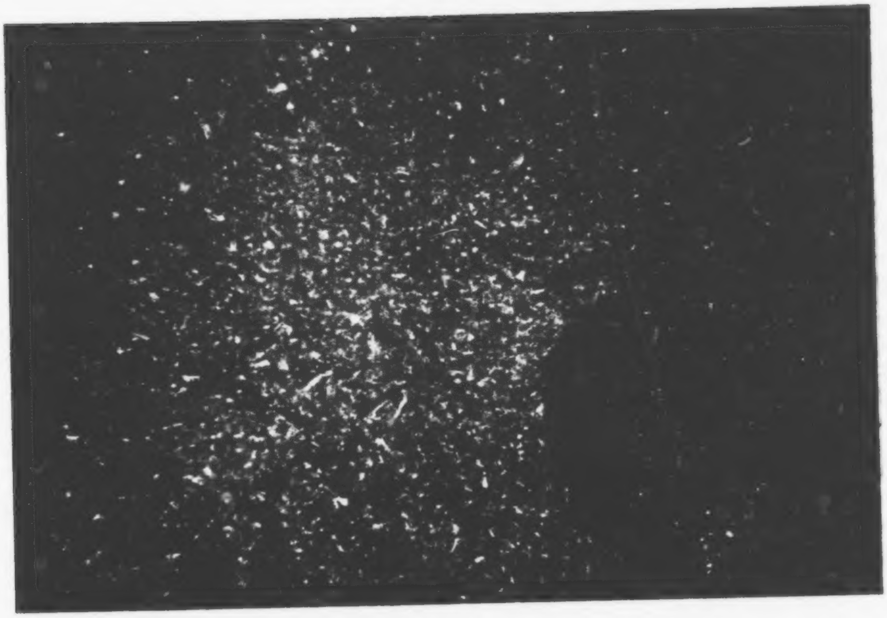

Figure 8. POINT AT WHICH PAN-ALASKA DISCHARGE PIPE ENTERS CRAB WASTE PILE

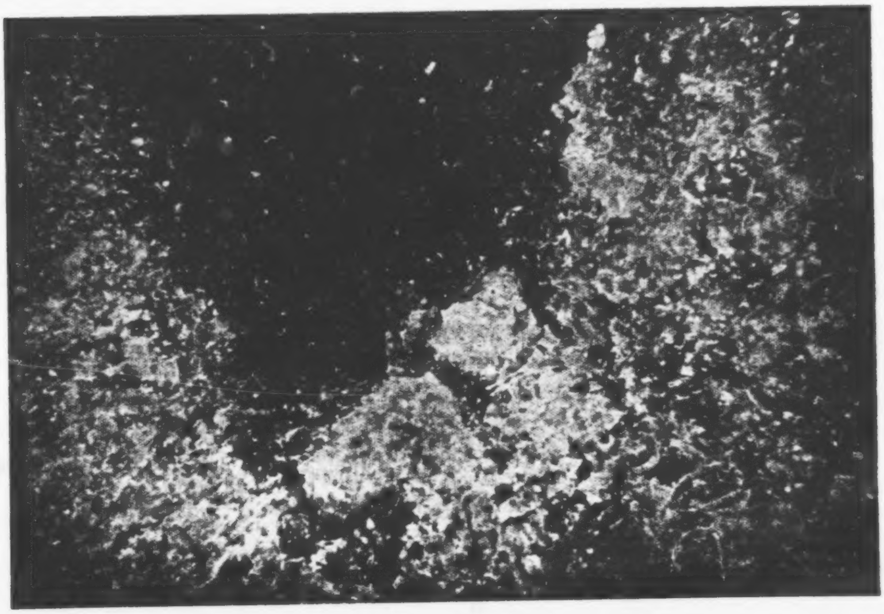

Figure 9. CLOSEUP OF PAN-ALASKA WASTE PILE SHOWING DECOMPOSED CONDITION OF WASTES REMAINING FROM 1978 TANNER CRAB SEASON

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the white microbial mat characteristic of older wastes is clearly visible here. In addition, distinguishable crab shell material is not as evident, indicating that some degradation has occurred since the wastes were deposited during the 1978 tanner crab season.

Although no photographs were taken during pile measurement dives, marine organisms observed by the divers were noted. At the Pacific Pearl pile the following were observed in September and October: one 4-foot wolf eel, several sculpins, miscellaneous bottom fish, sea anemones, sponges, and sea urchins. Many juvenile baitfish were also observed feeding over the pile (Figure 3). In January hundreds of diving ducks were observed diving to and feeding on the pile at a depth of 40 feet.

Wolf eels were observed on the Universal pile in September and October. Juvenile baitfish were present in September, while in January large numbers of small tanner crabs were congregated at the outer edges of the pile.

In the vicinity of the Vita pile juvenile baitfish, small sculpins, sea anemones, and sponges were observed in September and October. In January flatfish, sculpins, tanner crabs, and sea urchins were present.

Marine biota around the Pan-Alaska pile in September and October consisted of sea urchins, clams, juvenile baitfish, sculpins, sea anemones, and sponges. In January large numbers of tanner crab were present along with sea urchins, sea anemones, and a starfish on the discharge pipe.

At the Whitney-Fidalso outfall the groups of organisms present were the same as those at the Pan-Alaska outfall in September and October. In January sea urchins and tanner crabs were observed only at the edge of the pile.

In the vicinity of the Sea-Alaska outfall seals were observed in September and October. In September bottom fish, sea anemones, sponges, and sea bass were also present. The October biota consisted of juvenile baitfish, sponges, and sea anemones. In January only sea anemones, starfish, and sea urchins were present at both the Sea-Alaska and M/V Robert E. Resoff outfalls.

It is recognized that these observations do not provide a sufficient data base upon which to draw conclusions concerning any effects of crab wastes on marine biota. They do, however, indicate that the wastes are not creating a biological desert in the vicinity of the outfalls except where infauna and attached organisms become covered with waste.

There has been some controversy over underwater photographs of a control area taken by EPA divers during their recent crab waste pile studies in Dutch Harbor. The argument essentially revolves about whether EPA's selection of a control area that supported a dense and diverse attached community was representative of conditions in areas affected by crab waste discharges. The area selected by EPA, approximately 0.7 mile north of the Whitney-Fidalgo discharge area, corresponded to the approximate depth (about 50 feet) characteristic of the discharge areas, but was away from the influence of any waste discharges.

The EPA control area pictures most likely do accurately represent the type of attached and mobile benthic community structure to be expected in areas having a substrate similar to the control area. In this particular case, it is a medium-sized cobble bottom. What the EPA control area pictures do not reflect are the communities characteristic of other types of substrates occurring in the discharge areas. For example, the Pan-Alaska and Whitney-Fidalgo outfalls discharge onto mud-sand bottoms containing some rocks (see Figure 7). The shallow Vita pipe discharges into an area with a rocky bottom that has several large rocky reefs, some of which extend above the water surface. The deeper Vita discharge area used in 1977 has a cobble and sand bottom. Pacific Pearl discharges over a rock ledge onto a sloping rocky bank (see Figure 4). The Universal discharge area is also predominantly rock, containing small- to medium-sized cobble and some large rocks. Sand and gravel become more prevalent near the seaward edge of the pile. The bottom area in the vicinity of the Sea-Alaska, M/V Robert E. Resoff, and M/V Yardarm Knot outfalls is covered predominantly by rocks and kelp beds with some sand.

Portions of the Pacific Pearl, Universal, and the abandoned deep Vita discharge areas are the only areas that are comparable with the EPA control area with respect to similar substrate and depth. That all the discharge areas resembled the EPA control area before crab wastes were discharged should not be implied. The predominant substrate in the discharge areas and seaward of the waste piles is mud-sand and not the type that would support the attached control area community. Figure 6 provides some indication of the differences in community structure that can be observed on mud-sand and hard substrates. However, until a more accurate inventory of the amount of bottom area comprising the different substrate types and associated biota both in and away from waste-affected areas is obtained, the magnitude of benthic community destruction or disruption in the nearshore areas cannot be determined.

The fish and mobile benthic animals observed in the vicinity of the waste piles appear to be characteristic of Aleutian Island nearshore areas (Isakson, *et al.*, 1971; Simenstad, *et al*, 1977). What is not known is whether the species diversity and relative abundance of the fish and macroinvertebrate communities or any significant nursery areas have been affected by waste discharges. At present it is not known whether the wastes have caused mobile organisms to leave the discharge areas or have had an attractive effect for feeding purposes. A quantitative comparative study in waste-dominated and unaffected areas similar to that supporting the above-mentioned references would be required to make such a determination. It would also be informative to investigate the bioenhancement potential of the crab wastes. The wastes may provide a source of nutrients through mineralization during the decay process. Nutrients diffuse into overlying waters and are reincorporated into the marine food web.

PILE VOLUME MEASUREMENTS

The first series of dives to measure crab waste pile volumes was made between September 13 and 16, 1978. Since the red king crab season opened in the Dutch Harbor and Bering Sea areas on September 10 (Alaska Department of Fish and Game 1978) and actual processing was just beginning at the time of these dives, the September pile volume data were considered to represent pre-season waste pile volumes, except at Pacific Pearl where 1,791,393 pounds of king crab were processed between July 23 and September 12. The second series of dives was made mid-season between October 28 and 30. The amount of crab processed began declining in mid-November and the season was essentially over by the second week in December. Pacific Pearl and Pan-Alaska continued to process small amounts of crab into January 1979. The post-season dives were made between January 3 and 8.

In September, crab fishermen were very successful immediately and were unloading catches in Dutch Harbor within a few days after the season opened. Processors were at full capacity shortly thereafter. This situation resulted in a maximum amount of crab waste being generated by the processors and, consequently, created a worst-case situation with respect to the amount of waste discharged per unit time to nearshore waters. These conditions continued through most of October so that the waste pile volumes measured at the end of October can be considered to represent the net result of the greatest rate of king crab waste accumulation under present conditions.

Figures 10 through 15 depict the October and January pile dimensions as measured by the divers. The pre-season pile drawings are not included since in all cases the piles were smaller than those measured in October. These figures will be discussed in conjunction with the pile volume and discharged waste volume data.

PILE VOLUME AND DISCHARGED WASTE VOLUME CALCULATIONS

Table 1 summarizes the pile volume changes over time and compares these changes with the volumes of waste discharged through each discharge pipe or outfall.

There appears to be several mechanisms affecting the fate of deposited wastes and, consequently, any pile measurements made at a specific point in time. As waste piles increase in size, the additional weight can be assumed to cause some compaction of material nearer the bottom of the pile. Overall pile slumping can then occur as the pile increases and also as the structural strength of the shell fragments is lost due to degradation. Divers have observed the waste to be converted to a light flocculent-type solid as the shell is degraded. If discharged on a slope, wastes can also be expected to move downslope as pressure increases from the additional weight. Visual observations of deposited wastes and literature values indicate some degradation of shell material occurs on a time scale of several months. Soft tissues are degraded much more rapidly, probably within several weeks, and are also consumed by marine organisms. For

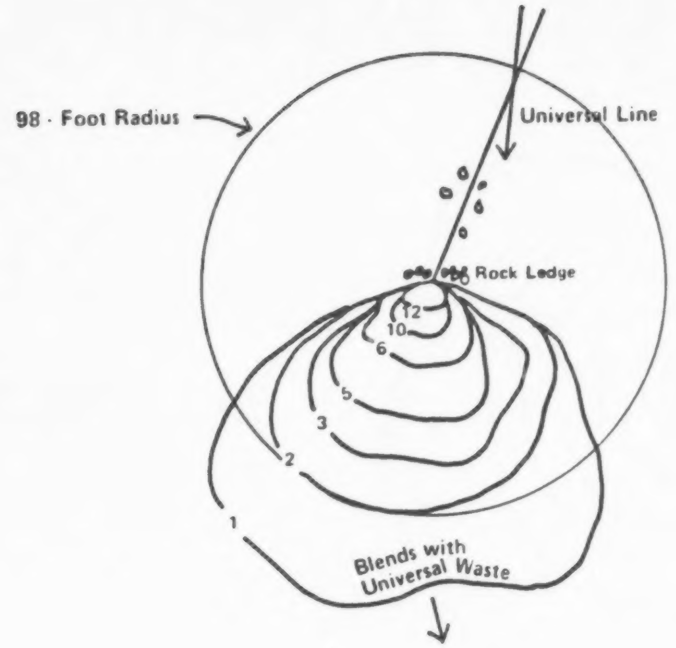

98 · Foot Radius
Universal Line
Rock Ledge
12
10
6
5
3
2
1
Blends with Universal Waste

Figure 10a
10/28/78

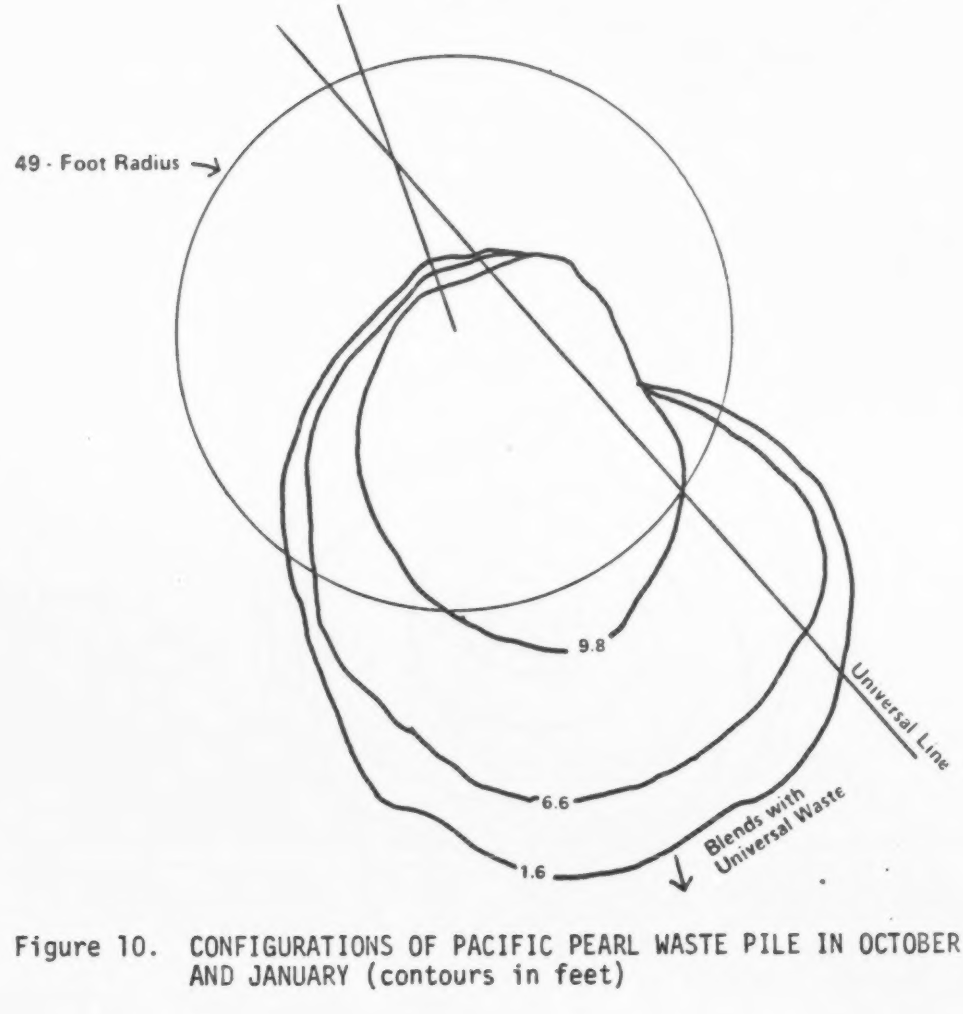

49 · Foot Radius
9.8
Universal Line
6.6
1.6
Blends with Universal Waste

Figure 10b
1/5/79

Figure 10. CONFIGURATIONS OF PACIFIC PEARL WASTE PILE IN OCTOBER AND JANUARY (contours in feet)

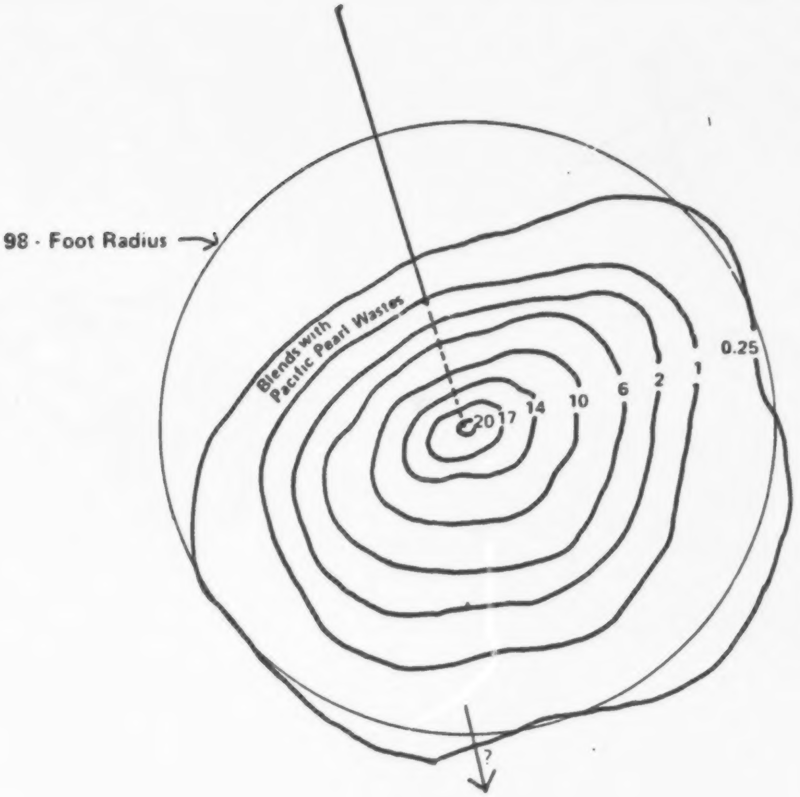

98 - Foot Radius
Blends with Pacific Pearl Wastes
0.25
1
2
6
10
14
17
20
?

Figure 11a
10/30/78

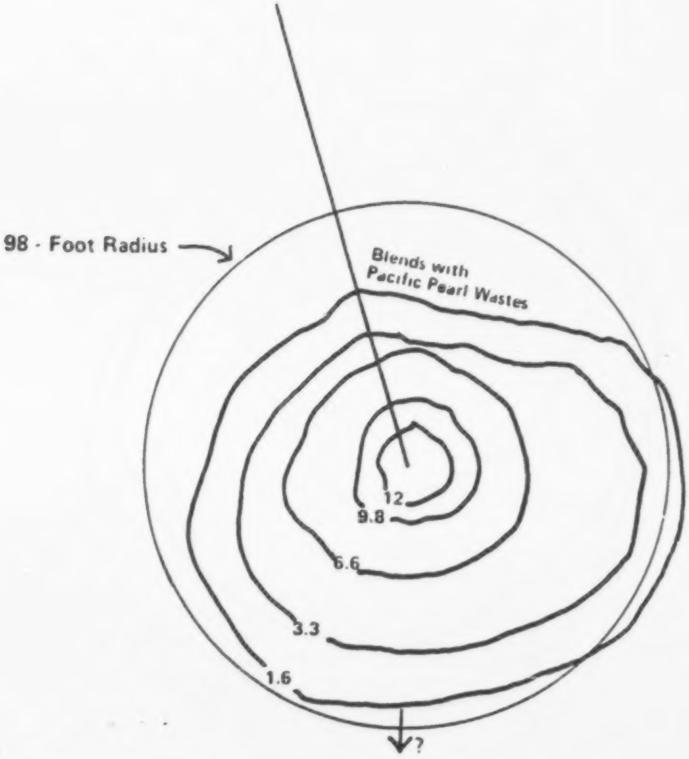
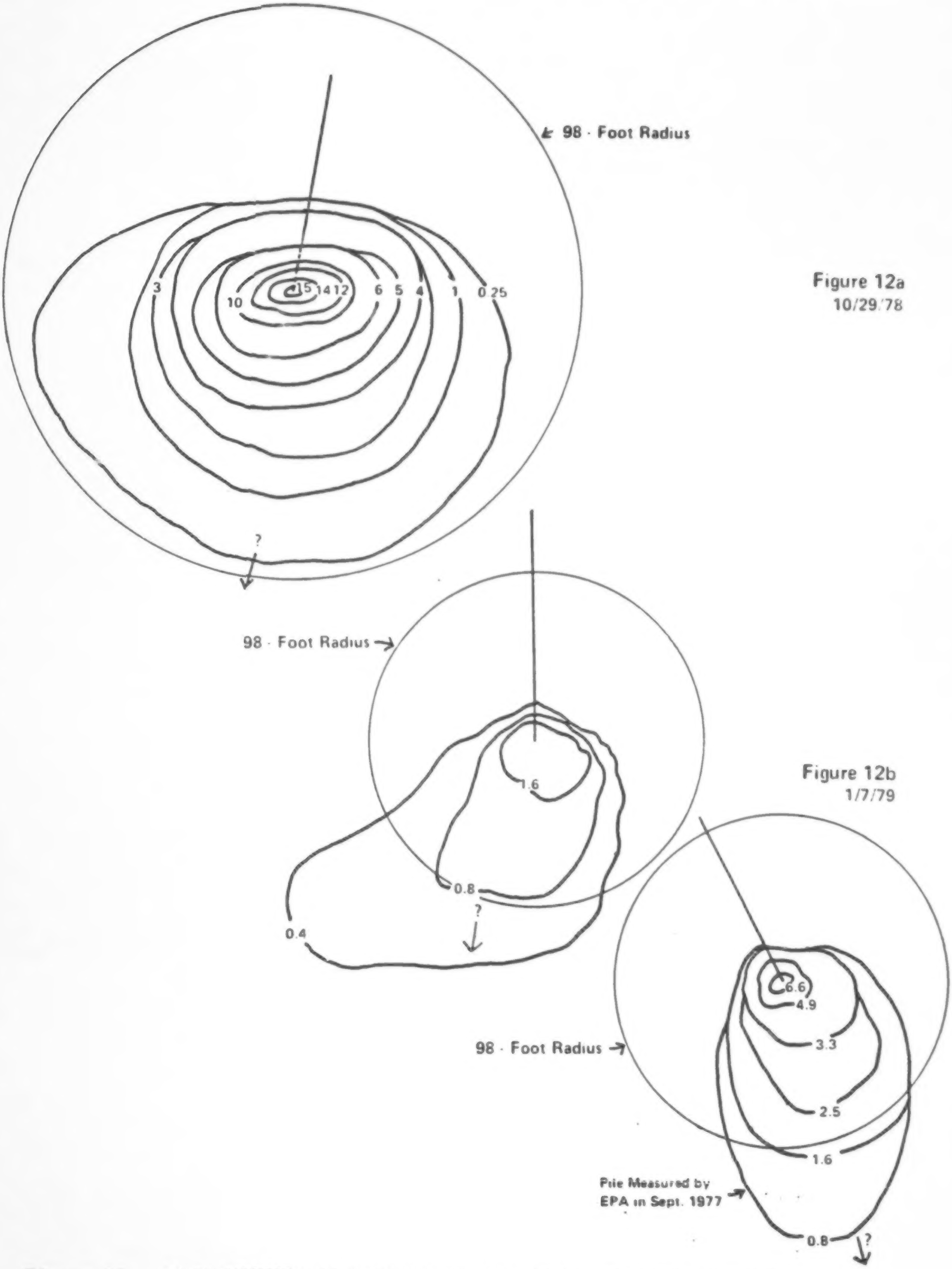

98 - Foot Radius
Blends with Pacific Pearl Wastes
12
9.8
6.6
3.3
1.6
?

Figure 11b
1/8/79

Figure 11. CONFIGURATIONS OF UNIVERSAL WASTE PILE IN OCTOBER AND JANUARY (contours in feet)



98 - Foot Radius
3
10
15
14
12
6
5
4
1
0.25
?
98 - Foot Radius
1.6
0.8
0.4
?
98 - Foot Radius
6.6
4.9
3.3
2.5
1.6
Pile Measured by
EPA in Sept. 1977
0.8
?

Figure 12a
10/29/78

Figure 12b
1/7/79

Figure 12. CONFIGURATION OF VITA WASTE PILE IN OCTOBER AND JANUARY (contours in feet)

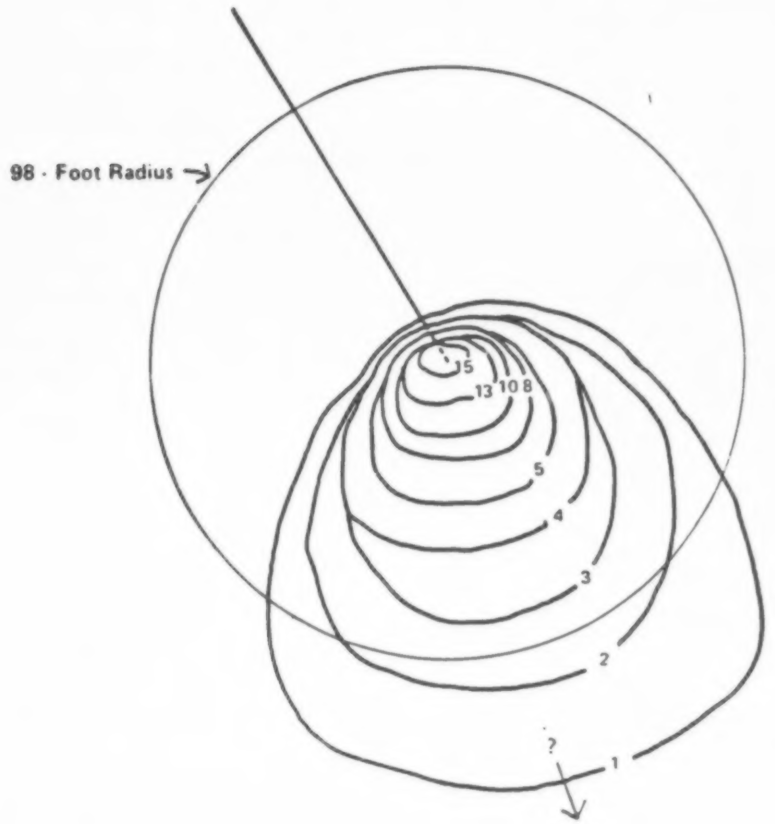

98 · Foot Radius
15
13
10
8
5
4
3
2
1
?

Figure 13a
10/28/78

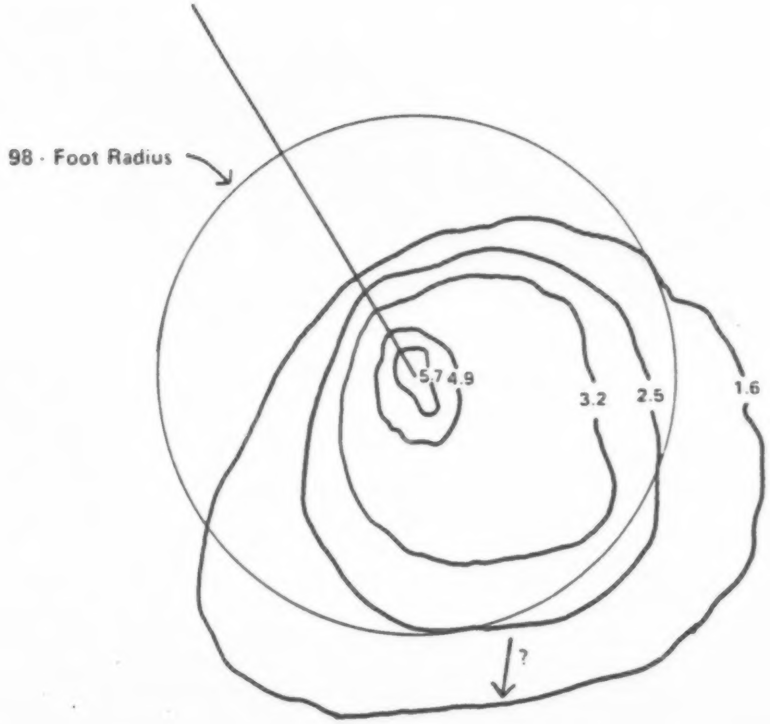

98 · Foot Radius
5.7
4.9
3.2
2.5
1.6
?

Figure 13b
1/3/79

Figure 13. CONFIGURATIONS OF PAN-ALASKA WASTE PILE IN OCTOBER AND JANUARY (contours in feet)

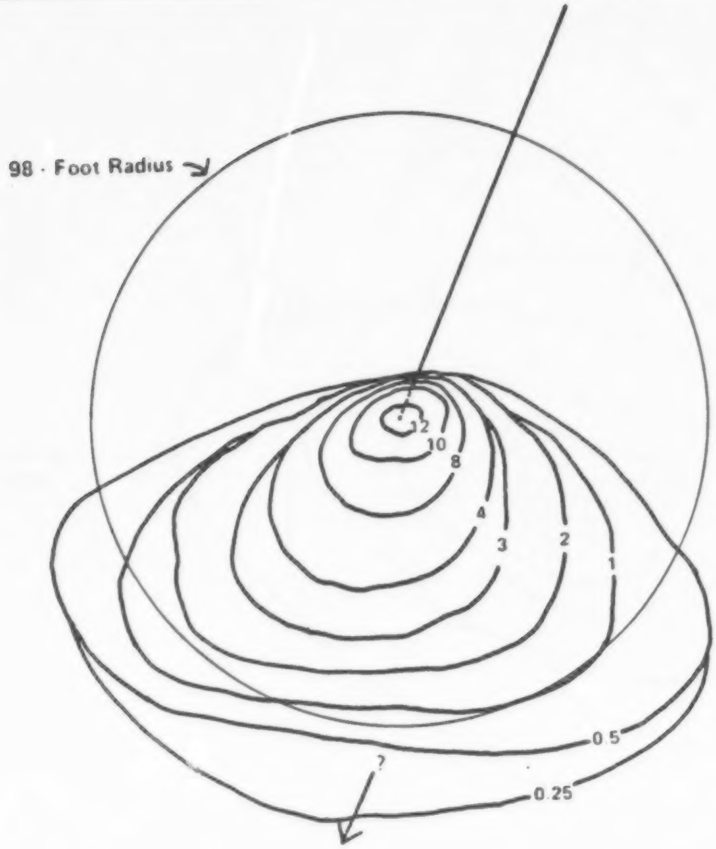

98 - Foot Radius
12
10
8
4
3
2
1
0.5
?
0.25

Figure 14a
10/29/78

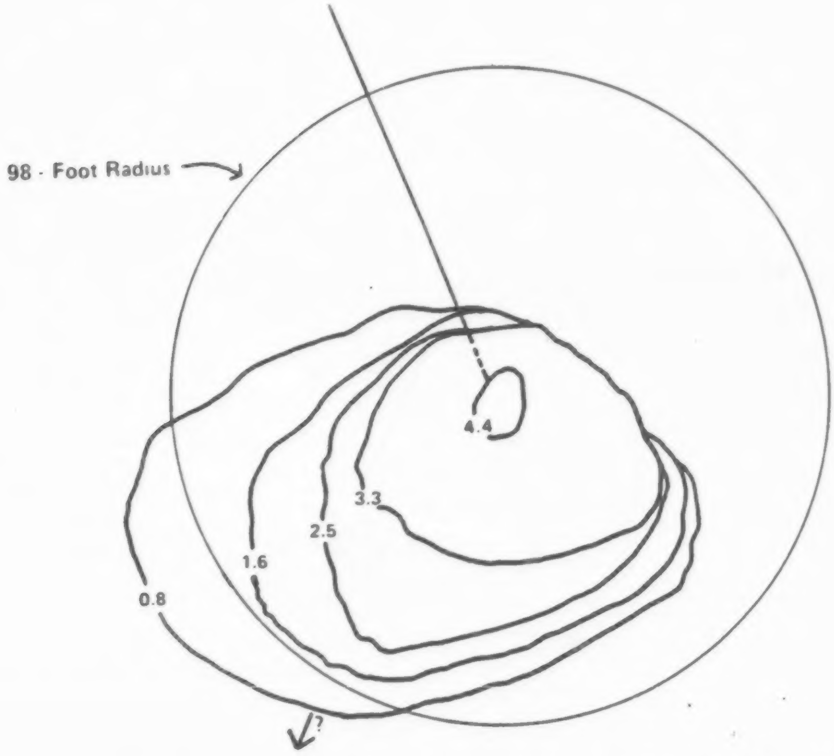

98 - Foot Radius
4.4
3.3
2.5
1.6
0.8
?

Figure 14b
1 / 3/79

Figure 14. CONFIGURATION OF WHITNEY-FIDALGO WASTE PILE IN OCTOBER AND JANUARY (contours in feet)

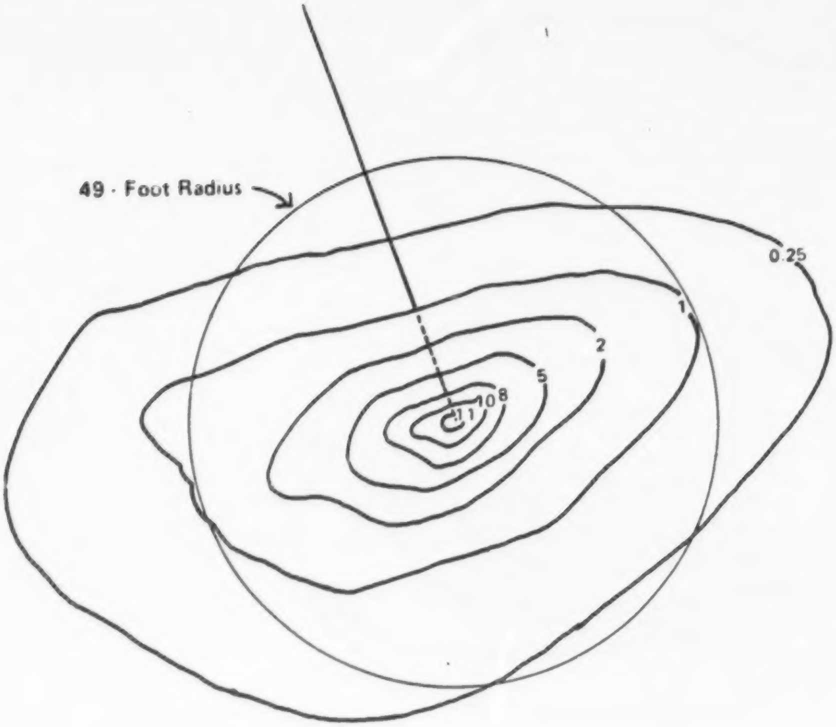

49 - Foot Radius
0.25
1
2
5
10
8
11

Figure 15a
10/29/78

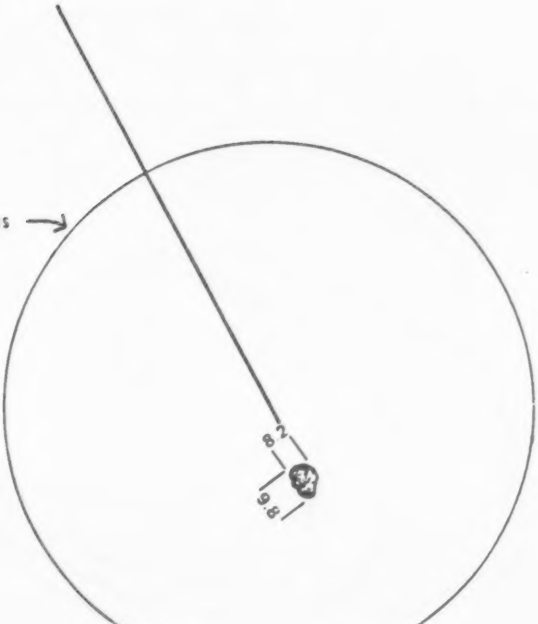

98 - Foot Radius
8.2
9.8

Figure 15b
1/5/79

Figure 15. CONFIGURATIONS OF SEA-ALASKA WASTE PILE IN OCTOBER AND JANUARY (contours in feet)

Table 1. RELATIONSHIP BETWEEN WASTE PILE VOLUME CHANGES AND KING CRAB WASTES DISCHARGED DURING 1978 SEASON

Discharger	Date Pile Measured	Pile Volume (ft^3)	Change in Pile Volume Between Measurements (ft^3)	Waste Discharged Between Measurements (ft^3)	Bottom Area Covered (ft^2)	Maximum Pile Depth (ft)
Pacific Pearl	9/13	29,678		6,653[a]	18,587	10
	10/28	41,416	+11,738	12,729	17,603	12
	1/5	54,527	+13,111	8,849	18,140	10
Universal	9/16	35,566			>32,000[b]	15
	10/30	66,831	+31,265	46,298	>32,000	20
	1/8	75,585	+8,754	11,447	>32,000	12
Vita	9/15	21,446			7,854	8.2
	10/29	36,364	+14,918	58,091	15,588	15
	1/7	13,200	-23,164	4,922	>21,062[b]	1.6
Pan-Alaska	9/14	49,305			>31,416[b]	10
	10/28	54,553	+5,248	10,185	>29,447	15
	1/3	49,810	-4,743	10,992	>32,008	5.7
Whitney-Fidalgo	9/14	25,986			>7,854[b]	10
	10/29	43,246	+17,260	28,738	>22,497	12
	1/3	31,100	-12,146	-0-	>15,224	4.4
Sea-Alaska	June '78[c]	11,769			4,418	8
	9/15	6,538	-5,231		1,963	10
	10/29	9,569	+3,031	63,237	10,148	11
	1/5	291	-9,278	3,247	81	1.6

---

[a] Waste discharged between 7/23 and 9/12.

[b] Total bottom area covered could not be determined because wastes were dispersing downslope into deep water.

[c] Measurements made at end of tanner crab season.

those wastes discharged into shallow areas or areas with strong currents or heavy wave action, dispersion is the dominant mechanism.

Because of the proximity of the Pacific Pearl and Universal outfalls, the waste piles blend at the 80-foot depth contour (Figure 10). Consequently, it was difficult for the divers to determine the source of the waste in this vicinity and explains why the Pacific Pearl pile appears to have a greater change in volume (+13,111 cubic feet) than can be accounted for through wastes discharged (8,849 cubic feet) between October and January. Pacific Pearl discharges on a rather steep rocky portion of the bottom with rocky ledges on both the north and south sides. The ledges force deposited wastes downslope toward the Universal pile, as evidenced by the rather consistent amount of bottom area covered and maximum pile depth.

Measurements of the Universal waste pile indicate a greater discrepancy between pile volumes and waste volumes discharged. Because the outfall discharges at 110 feet, the divers were only able to measure wastes to a depth of 120 feet although it was evident that the wastes occurred at greater depths (Figure 11). Thus, it appears that 25 to 30 percent of the Universal wastes may have moved into deeper water during this study. The decrease in maximum pile height from 20 to 12 feet provides evidence of compaction and slumping.

In 1978 Vita Food Products discharged wastes at approximately the same location as in previous years but at a depth of only 20 feet. In 1977 the discharge point was at 75 feet. As indicated in Table 1, about four times as much waste was discharged between September 15 and October 29 than accumulated in the pile. Between the October and January measurements there was a 64-percent decrease in pile volume coupled with a decrease in maximum pile height from 15 to 1.6 feet. The wastes were spread over a larger area in January and appeared to be moving downslope (Figure 12). Wave action was assumed to have been the dominant dispersal mechanism.

On January 7 the divers located and measured the deeper waste pile created by Vita discharges in 1977. This pile was 6.6 feet deep, covered 16,474 square feet, and contained 25,234 cubic feet of waste. As indicated in Figure 12, there was a downslope movement of wastes along the seaward edge of the pile.

Pan-Alaska discharged approximately equal amounts of waste before and after the October waste pile measurement. One would have expected the pile to increase in volume proportionately. Instead, the volume decreased between October and January by 4,743 cubic feet. As with the Universal pile, the maximum extent of bottom area covered was not defined because of movement of the wastes into deeper water (Figure 13). It appears that the decrease in pile size was due to a combination of compaction/slumping, downslope movement, and wave action. Evidence for wave action was provided by the divers who observed that the lower area of the pile was characterized by ripple marks.

Of the 28,738 cubic feet of waste discharged prior to October 29 by Whitney-Fidalgo, 17,260 cubic feet or 60 percent accumulated in the pile. The wastes along the seaward edge of the pile were observed to be dispersing toward deeper water so that the total bottom area covered could not be defined. In contrast to Pan-Alaska, Whitney-Fidalgo did not discharge any waste after October 29.

The Whitney pile decreased in volume by 12,146 cubic feet between October 29 and January 3 and exhibited a rather dramatic change in shape (see Figure 14). The pile decreased from a maximum depth of 12 to 4.4 feet and spread to the north. It can be hypothesized that wave-generated bottom currents flowed downslope counter to the wave trains breaking along this section of coastline and moved the wastes in a northerly direction.

At the Sea-Alaska outfall, a dive was made in June 1978 by Dutch Harbor Divers to measure the waste pile at the end of tanner crab season. During the summer of 1978 there was a net loss of 5,231 cubic feet of wastes (Table 1). During the height of the 1978 king crab season the amount of waste discharged was 20 times greater than that which accumulated in the vicinity of the outfall. The maximum bottom area covered was 10,148 square feet. Although Sea-Alaska was the largest producer of waste during the 1978 king crab season, waste accumulations five weeks after processing ended were negligible (Figure 15).

The M/V Robert E. Resoff was added to the Sea-Alaska complex in 1978 to increase production, and a separate discharge line was installed parallel to the older line. The new line is closer to shore and discharges in 40 feet of water in contrast to 50 feet for the older line. A dive on the Resoff line was made on January 5, 1979. There was no waste pile and only scattered pockets of shell, all less than an inch deep, within several hundred feet of the outfall. The Resoff had discharged 8,998 cubic feet of waste between the beginning of the season and November 20.

Whitney-Fidalgo brought the processing vessel M/V Yardarm Knot into Dutch Harbor in 1978 and installed an outfall across the spit from the Yardarm Knot's moorage 400 feet offshore in 20 feet of water (Figure 1). Between September 18 and October 24, 9,982 cubic feet of wastes were discharged, but no wastes were observed around the outfall at the end of the season.

A more complete history of waste pile dynamics during a processing season was compiled by Pan-Alaska during the 1977 tanner crab season. Beginning April 22, Gene Anderson, an oceanographer from the University of Washington, made biweekly dives to measure the pile and, as part of his reports, provided some detailed descriptions of his observations. Excerpts from his dive reports are included here verbatim because they provided a great deal of insight as to how the waste pile changed over time, aided in interpreting the pile volume data, and indicated some effects on marine life. Table 2 summarizes the pile changes as derived by planimetry from Anderson's pile drawings.

> April 22: "Today I made my second dive at the effluent line and placed four marker posts at 100 feet from the pile in each of four

compass points (station 1 was offshore from the end of the outfall), station 2 to the north, station 3 inshore, and station 4 to the south). I found four inches of shell and debris at station 1. Stations 2 and 4 had roughly about two-thirds of the sediment hidden by shell and not measurable, and station 3 had one-half or less (of the sediment) covered, again not measurable. The majority of the shell was ground up fairly small with a few larger whole arms and body shells and many rubber bands.

"The marine life consisted of a few clams and anemones. About one-half of the clams I saw were empty shells and the other half were alive. It is hard to make any deductions on the mortality due to shell buildup without checking the percent of live versus dead clams in an unaffected area."

May 6: "The size of the pile has grown by about one-half and is now 8 to 10 feet above the level of the pipe, so the pile is now close to 25 feet deep. Station 1 was still the deepest and had 6 inches of shell. Station 2 was next with just under 1.5 inches of shell, and station 4 had exactly 1 inch of shell. Station 3 was still relatively undisturbed and had about half the sediment visible and the shell buildup was not measurable."

May 20: "The effluent pile has remained at about the same depth, but has pretty well rounded over at the top and is much broader. Station 1 is still right at the edge of the pile and has 7 inches of shell buildup. Station 2 is pretty well away from any appreciable buildup and has 1.5 inches of shell. Station 3 is a good ways away from the perimeter of the pile and has less than 0.5 inch over the bottom all around it. Finally, station 4 is much like 2 and has about 1.25 inches of shell buildup."

June 7: "The effluent pile has grown to such a size that it has completely covered the end of the pipe as well as the frame it is supported on. Most of the shell, however, is apparently still able to penetrate to the top of the pile. The center of the pile is very fluid and somewhat hollow, which makes the whole pile look just like a volcano erupting with air bubbles and shell spewing from it. The sides of the pile are quite steep and then flatten out rapidly at a shell depth of around 2 feet.

"On this dive there were many more times the number of clams on the sediment surface than before. There were hundreds of them in all areas where the shell depth was 2 inches or less, and many of them left trails where they had been crawling from one place to another.

"The depth of shell at the different stations was much the same except for station 1, which had grown from 7 to 10 inches. Station 2 had 1.5 inches of shell, and station 3 had 0.75 inch of buildup. Station 4 had grown slightly in shell to a depth of 1.5 inches."

June 23: "The effluent pile seems to have rounded off and slumped down a little during the few days we were not processing. The top of the pile is much flatter with a large, rounded-out crater and less steeply sloping sides. The depth of the shell at Station 1 has decreased from 10 inches back to 7 inches and is an indication that the pile has settled downward somewhat. Station 2 has grown to 2 inches of shell, and station 3 has grown to 1 inch. Station 4 has also grown slightly to a depth of 1.75 inches.

"The marine life which is represented primarily by clams seems to be showing a much more adverse reaction to the shell debris. There are now many small empty shells at the surface which I had not noticed before, and the large clams are still crawling around over the sediment surface. Most of them are still alive but react fairly slowly when touched and a few didn't close at all.

July 11: "The effluent pile has now rounded off to a big slush pile of muddy crab debris. A large portion of the pile has been reduced by a combination of factors. Much has apparently washed away as exemplified by the complete lack of rubber bands which are light and easily carried away. Some has obviously sunk and compacted downward since there are no large crab shells or large pieces of debris apparent at the pile surface. Also, a small amount has most likely been eaten by various marine organisms which is indicated by numerous shrimp, eels, a few flounder, small crabs, and large sculpins on or near the pile. There are also very distinct wave ripple marks over the whole pile, giving it an aged look.

"The overall size of the pile has been reduced approximately one-third since processing stopped (June 21), and the area surrounding the pile which was lightly dusted with debris is practically barren again. The shell depth at station 1 is now down to just 3 inches to 5 inches depending on whether the measurement is made in a trough or at a peak of a ripple. Stations 2 and 3 are back to 0.5 inch, and station 4 has 0.75 inch of debris.

"The clam community seems to have completely vacated this area since I was unable to find one live clam or any trails. There were a few empty shells scattered around but most have been there for awhile. There were a couple of dead small crabs and one very large dead buffalo sculpin on the top of the pile."

Table 2. PAN-ALASKA WASTE PILE VOLUME CHANGES DURING THE 1977 TANNER CRAB SEASON

Date Pile Measured	Pile Volume (ft^3)	Change in Pile Volume Between Measurements (ft^3)	Bottom Area Covered (ft^2)	Maximum Pile Depth (ft)
4/22	24,340		23,845	16
5/6	49,772	+25,432	30,202	25
5/20	63,438	+13,666	31,625	25
6/7	80,638	+17,200	47,488	25
6/23	86,499	+5,861	59,847	20
7/11	59,240	-27,259	31,827	12

WASTE PILE VOLUME REDUCTION RATES

The rather dramatic volume reduction of the Pan-Alaska waste pile just after the end of the 1977 tanner crab season allows an estimate to be made of its reduction rate. During the 18 days between the June 23 and July 11 measurements, the pile volume was reduced by 27,259 cubic feet or 31.5 percent for an average rate of 1,514 cubic feet of 1.75 percent per day. This rate is probably a somewhat high estimate more accurately reflecting a combination of pile compaction and slumping as well as actual disperson or degradation since at this rate the wastes present on June 23 would have disappeared within 57 days. Actually, some wastes were present when EPA personnel measured this pile on September 26, 1977. By this time king crab processing had already begun, but there was still evidence of old wastes remaining (Karna 1978, Figure 16).

Brown and Caldwell (1978) reviewed the literature on the rates of mineralization of chitinous material in the marine environment and found that at least partial degradation can occur within three months. This agrees with visual observations made on Dutch Harbor crab wastes (see Figure 9). Because there are additional factors contributing to the reduction of waste pile volumes, an overall reduction rate would appear to be the most meaningful.

Several estimates of pile volume reduction rates can be made from the 1978 king crab waste data presented in Table 1. Whitney-Fidalgo did not process after their waste pile was measured on October 29. From then until January 3 the pile volume decreased by 12,146 cubic feet for an average rate of 184 cubic feet per day. This represents a pile reduction of 28 percent in 66 days of 0.43 percent per day.

Vita and Pan-Alaska continued to process crab through the January pile measurement dates, but since there were net reductions in both pile volumes, a net reduction rate could be estimated. Between October 29 and

January 7 the Vita pile was reduced at an average rate of 401 cubic feet or 1.1 percent per day, while the Pan-Alaska pile decreased 235 cubic feet or 0.43 percent per day. These reduction rates include the wastes discharged between the October and January pile measurement dates. Since the Pacific Pearl and Universal waste piles increased in volume throughout the season, any volume reduction estimates are precluded.

Because the Whitney-Fidalgo and Pan-Alaska waste piles occupy the same general area, are at similar depths (40 feet), and are subjected to similar reduction mechanisms, it is not surprising that the percentage reduction rates for these piles are the same (0.43 percent per day). In comparison, the Vita discharge in only 20 feet of water has nearly a threefold greater percentage reduction rate (1.1 percent per day), indicating the better dispersive nature of the shallower nearshore waters.

On the east side of Amaknak Island waste dispersion equaled or exceeded 100 percent of the wastes discharged during the season plus pre-season accumulated wastes.

Crab was last produced by Sea-Alaska on November 24. A pile containing 9,569 cubic feet on October 29 plus 3,247 cubic feet discharged between October 29 and November 24 was dispersed to the extent that only 291 cubic feet remained in the pile on January 5. If it is assumed that all dispersion occurred after November 24, the dispersion rate is 298 cubic feet per day. However, 63,237 cubic feet of wastes were discharged between September 15 and October 29, while only 3,031 cubic feet accumulated in the pile, indicating that dispersion may be occurring on a more continuous basis in this area. This dispersion of 60,206 cubic feet of waste in 44 days results in an average dispersion of 1,368 cubic feet per day. The total waste dispersed during the king crab season was 72,731 cubic feet in 112 days for an average rate of 649 cubic feet or 0.89 percent per day. This can be compared to the 1978 summer dispersion rate of approximately 58 cubic feet or 0.5 percent per day.

The M/V Yardarm Knot discharged 9,982 cubic feet of waste during 36 days of production. No accumulated wastes remained at the end of the season. Similarly, the M/V Robert E. Resoff outfall had no accumulated wastes around it on January 5 after discharging 8,998 cubic feet between September 15 and November 20. Considering all three outfalls crossing the spit, a total of 91,711 cubic feet of crab wastes were effectively dispersed east of Amaknak Island during the 1978 king crab season. The average dispersion rate over a 112-day period was 819 cubic feet or 0.89 percent per day.

RECENT TRENDS IN DUTCH HARBOR CRAB WASTE PRODUCTION

At a January 12, 1979, meeting attended by representatives of the crab processors and EPA personnel, the point was discussed that waste discharged to nearshore waters had been reduced over recent years because of changes in market demand, i.e., there were now less pounds of meat and more pounds of sections being produced so that less solid waste was being generated per pound of crab processed.

Table 3 is a compilation of production data obtained from those companies participating in this study. The live crab purchased and products produced figures do not represent the total amount of crab processed in Dutch Harbor for the years indicated because some records were fragmentary or unavailable. However, since all the major processors are included, the trends as indicated by the percentages are considered valid.

Meat production as a percent of live crab purchased has declined steadily for both king and tanner crab. The amount of meat produced from king crab has remained rather constant, while tanner crab meat production has been almost completely eliminated. Both the pounds of sections and the percentage of sections produced have increased steadily.

The more important figures in Table 3 are the last two columns describing solid waste production. The total amount of solid waste produced has increased over time because of the increased pounds of king and tanner crab processed. However, the solid waste produced as a percent of live king crab dropped from 45.7 to 25.6 percent due to the shift to greater section production. With tanner crab a similar trend exists with solid waste production decreasing from 29.7 to 20.1 percent in three years.

To date the amount of crab waste generated by the processors has been calculated using the pounds of live crab purchased and the pounds of products produced. The waste figures so derived represent the total waste produced, i.e., fluids lost during butchering and cooking, as well as solids. The products as a percent of live crab purchased have been reported to average 60 percent for sections and 20 percent for meat or, conversely, about 40 percent and 80 percent waste is produced for sections and meat, respectively. Since there is about a 20 percent of live weight fluid loss for both tanner and king crab, the percentage of solid waste discharged to nearshore waters is considerably less than the figures quoted above.

The minimum amount of solid waste that would be generated would occur in the situation where all processors produced 100 percent sections. The 1978 tanner crab data essentially represent that situation. Consequently, the Dutch Harbor tanner crab solid waste load to be expected would be about 20 percent of the amount of live crab purchased. In comparison, Bray (1978) obtained an 18.8-percent solid waste figure for tanner crab section production from examining various waste components.

Solid waste percentages of live king crab purchased were calculated from data obtained from those processors producing 100 percent sections during the 1978 season. The range was from 12.4 to 21.7 percent with a mean of 15.4 percent. Bray's (1978) solid waste percentage for king crab sections was 17.5 percent. Using these percentages, the maximum solid waste load to be expected for 100 percent king crab section production can be calculated for any estimated live crab purchases.

If some king crab meat is continued to be produced, the solid waste generated can be expected to range between 55 and 58 percent (mean is 56.6 percent) based on data from processors that had 100 percent meat production lines during the 1978 season. These percentages are the same as those obtained by Bray (1978).

Table 3. RECENT DUTCH HARBOR CRAB PRODUCTION DATA

	Live Crab Purchased (lb)	Meat Produced (lb)	Meat as % of Live Crab	Sections Produced (lb)	Sections as % of Live Crab	Total Products Produced (lb)	Total Products as % of Live Crab	Total Waste Produced (lb)	Total Waste as % of Live Crab	Solid Waste Produced (lb)	Solid Waste as % of Live Crab
King Crab											
1975	21,933,928	3,613,813	16.5	3,910,200	17.8	7,524,013	34.3	14,409,915	65.7	10,023,129	45.7
1976	26,747,360	3,208,101	12.0	9,310,780	34.8	12,518,881	46.8	14,228,479	53.2	8,879,007	33.2
1977	30,376,947	2,728,952	9.0	13,550,142	44.6	16,279,094	53.6	14,097,853	46.4	8,022,464	26.4
1978	57,429,767	3,693,017	6.4	27,559,987	48.0	31,253,004	54.4	26,176,763	45.6	14,690,810	25.6
Tanner Crab											
1976	9,174,292	365,160	4.0	3,330,676	36.3	3,695,836	40.3	5,478,456	59.7	3,643,598	39.7
1977	27,423,678	450,354	1.6	15,570,649	56.8	16,021,003	58.4	11,402,675	41.6	5,917,939	21.6
1978	48,351,285	50,000	0.1	28,907,541	59.8	28,957,541	59.9	19,393,744	40.1	9,723,487	20.1

From a solid waste disposal viewpoint, the important consequence of production changes from meat to sections is that 41 percent less solids are produced per pound of live crab processed. When the above percentages are used, a more accurate estimate will be obtained for the amount of solid wastes being discharged to the nearshore waters.

EFFECTS OF CRAB WASTES ON WATER QUALITY

The effects on water quality of crab wastes discharged to nearshore waters were determined by evaluating water quality data collected in the vicinity of the waste piles and adjacent areas. Water quality sampling programs in October 1976 (Stewart and Tangarone 1977), October 1977 (Colonell and Reeburgh 1978), March 1978 (Brown and Caldwell 1978), and June 1978 (Feder and Burrell 1978) provided the data base for this evaluation.

Dissolved oxygen data indicated that oxygen levels were always greater than 8 mg/l with the majority of concentrations being greater than 10 mg/l in bottom waters just offshore from the piles on the west side of Amaknak Island. The continuously lowered dissolved oxygen concentrations characteristic of the deeper waters of Dutch Harbor and Iliuliuk Harbor, where the majority of processing wastes had been discharged prior to construction of the outfalls to the west side of Amaknak Island and across the Dutch Harbor spit, do not occur at the existing waste disposal areas.

Changes in ammonia and sulfide concentrations and light transmittance in the vicinity of the waste piles were the only water quality parameters that differed from open waters or nearshore waters not in the vicinity of the waste piles.

Light transmittance decreases due to increased turbidity were limited to those areas where the effluent plumes rose to the surface above the outfalls and also to the bottom areas in the immediate vicinity of the waste piles. Turbid conditions exist above and around the piles due to the settling of the ground wastes from the outfalls and also from the resuspension of the finer particulates generated through decomposition of the wastes. Since increased turbidity is very localized and involves only a small volume of water, it is not considered to be a problem from a marine biological perspective. It does, however, have some aesthetic visual connotations.

Slightly elevated average ammonia concentrations (0.098 mg/l) in waters offshore from piles on the west side of Amaknak Island were detected by Feder and Burrell (1978). Throughout the rest of Unalaska Bay the concentrations were 0.084 mg/l or less. The higher concentrations were limited to waters 65 to 130 feet deep in the basin south of Hog Island. In Captains Bay ammonia concentrations increased with depth. An average concentration of 0.098 mg/l was found only below 130 feet. The elevated ammonia level off Amaknak Island is not considered to be significant.

An increased level of sulfide appears to be the major water quality abnormality associated with the current ground crab waste disposal practices. Sulfide will be generated anaerobically during decomposition of the crab wastes, particularly the tissue protein portion of the waste, and will continue to be generated as long as degradable organic matter remains. Sulfide can exist in three forms in the dissolved state depending on the pH of the water. Within the pH range most likely to occur in the vicinity of Dutch Harbor, the percent of sulfide ion that is in the form of undissociated hydrogen sulfide (H_2S) will range from about 40 to 5 percent or, conversely, 60 to 95 percent will be in the ion form HS^-. The toxicity of sulfide is derived primarily from H_2S rather than the sulfide ion (NAS 1973).

Sampling conducted by EPA (Karna 1978) and the University of Alaska (Feder and Burrell 1978) as well as diver observations indicated that sulfide concentrations were detected only within a few feet of the piles. Water current measurements, density data, and dissolved oxygen concentrations indicated that the waters have reasonably good mixing and are highly oxygenated in the areas where crab wastes are currently being discharged, thereby lessening the probability that high concentrations of sulfide will exist outside the immediate vicinity of the piles.

The most pertinent data on solid waste generation of sulfide can be found in Pratt *et al.* (1973). Although this study dealt with compacted household garbage of which the majority of organic solid material was paper, their observations on sulfide dynamics appear to be applicable to the Dutch Harbor situation. These investigators found that the diffusion rate of H_2S from wastes was on the order of 10^{-5} cm^2/sec, while rates of dispersion of overlying waters varied from 1 to 10 cm^2/sec. Accordingly, there was a reduced likelihood of toxic H_2S levels in overlying water other than in the boundary layer in contact with a waste deposit. Although not directly comparable with dispersion rates, bottom current velocities measured along the west side of Amaknak Island were on the order of 1 to 11 cm/sec (Brown and Caldwell 1978). These velocities indicate a significantly greater overlying water dispersion rate than sulfide diffusion rate from the waste piles.

EFFECTS OF CRAB WASTES ON MARINE ORGANISMS

Crab wastes could cause mortality of marine organisms by creating toxic conditions through sulfide production and by smothering attached and burrowing organisms. Detrimental effects could also involve eliminating food sources and spawning or nursery areas. On the other hand, the return of ground crab wastes to the nearshore marine environment could have beneficial effects by providing a food source (soft tissues) and enriching the sediments after degradation outside the immediate disposal area.

Hydrogen sulfide in both bottom sediments and the water column can have a toxic effect on marine organisms. It was suggested that concentrations of sulfide equal to or exceeding 0.01 mg/l constitute a hazard in the marine environment, and levels less than 0.005 mg/l present minimal risk of deleterious effects with the pH maintained within a range of 6.5 to 8.5 (NAS 1973).

Sulfide sampling by Karna (1978) and Feder and Burrell (1978) indicated sulfide levels above the recommended level. It should be noted that these samples were collected very near waste piles or actually were mixtures of water and waste sludge. There are too few data to define the frequency of occurrence or duration of toxic conditions. Concentrations noted would doubtless become very dilute within a few feet of the pile.

As mentioned by Pratt *et al.* (1973), the effect of sulfide on epifauna and mobile animals will depend on the dispersion rate in the overlying water. H_2S will be present in oxygenated waters around disposal sites, but little information is available on its attraction or repulsion of mobile animals.

Since observations of marine life around the waste piles indicate that there are not consistent toxic sulfide conditions existing, it is most likely that the surface of the waste pile remains aerobic, but that the interior portions of the pile are anaerobic. The surface of the waste pile could possibly be colonized by small marine organisms that are tolerant of the low oxygen levels and the presence of sulfide that exist below the surface of the pile, but it is more likely that colonization has not been observed because the shell particles do not provide a suitable substrate for organisms other than those affecting decay.

Some effects of crab wastes on marine organisms as observed in the immediate vicinity of the waste piles were presented in the section pertaining to the underwater photographs and diver observations of marine life. Smothering of attached organisms and infauna appears to be the most prevalent effect of the initial deposition of wastes on the bottom, even where wastes are as little as an inch or two deep. The extent of smothering initially involves the immediate bottom area around each outfall. The actual amount of bottom area covered fluctuates in conjunction with wastes produced during the processing seasons and the magnitude of pile reduction forces. Once the organisms are eliminated, there is not a rapid recolonization of the hard substrates where waste has dissipated and the surfaces are again exposed. There is no information on the recolonization of the soft substrates by burrowing organisms.

In view of the above considerations, the maximum area covered should be used when estimating the extent of bottom area disturbed. As indicated in Table 1, the maximum bottom area covered by the main piles during the 1978 king crab season totaled at least 126,000 square feet (3 acres). As previously mentioned, the divers were unable to find the seaward edge of the piles on the west side of Amaknak Island due to depth limitation (see Figures 10 through 14). There appears to be a net movement of waste material in a seaward and downslope direction from each waste pile. The benthic sampling program by the University of Alaska in the deeper waters of Unalaska Bay helped to define the fate of the crab wastes moving downslope from the areas occupied by the piles. It should be noted that the interim report included only field notes made when the benthic samples were collected. These results thus constitute a qualitative analysis. A more detailed analysis and discussion of species composition by station will be included in their final report. Consequently, there may be some conditions described later which will differ from the general impression originally obtained by Feder and Burrell (1978), but it is unlikely that the overall trend observed and discussed below will be significantly altered.

A grab sample of bottom material from the Universal outfall area yielded new shell material overlying many centimeters of old black waste. The sample had a nauseating H_2S odor and no living organisms were observed.

Moving offshore to approximately 0.2 mile, samples were taken in line with the outfalls and at three stations to the north of the Pan-Alaska and Whitney-Fidalgo outfalls. A variety of bottom types were found including sand, black sediment, sandy silt, and fine gravel to cobbles. A few organisms were found in most samples. Some of the samples had a strong sulfide smell and some had "fishy" organic smells. At Station 3I north of the outfall no sulfide was noted, but a crushed shell and sand mixture was found, indicating some northward dispersion of ground shell.

At stations located further offshore (0.3 to 0.7 mile), sediments were silty-sand or silt, some of which were black and had strong organic smells but no sulfide odors. Organisms were found in all samples.

Additional stations sampled throughout Unalaska Bay indicated a variety of organisms and substrates, some having organic odors, but all appeared to be uninfluenced by processing wastes.

The University of Alaska's results indicate that the wastes moving downslope into the deeper waters off the west side of Amaknak Island are decomposed to an organic sludge still maintaining the "fishy" organic odor characteristic of its source, but apparently not harmful to organisms by the time it has moved offshore 0.3 mile or more. It appears that this material provides an adequate substrate for burrowing organisms in contrast to the partially degraded wastes further inshore and in the piles. In addition, these sediments are aerobic throughout the year (see water quality section of this report and Feder and Burrell, 1978). The lack of sulfide odors and identifiable crab shell material in samples from 0.3 mile or more offshore indicates that complete degradation presently occurs within 0.3 mile of the discharge areas. Since most outfalls had been in operation about two or three years, it appears that complete degradation of crab waste can occur within this time frame. A definitive statement as to whether the bottom areas beyond 0.3 mile are being enriched or inhibited by the waste-derived sediment will have to be deferred until the quantitative data are available.

The total amount of bottom area affected can be estimated if we assume that there are "bands" of waste 200 feet wide moving downslope from each waste pile. Based on Feder and Burrell's (1978) preliminary results, 0.3 mile appears to be the seaward limit. Since the Pacific Pearl and Universal piles are essentially combined, there are four separate bands, each covering a maximum of 316,800 square feet or 7.3 acres, for a total of 29 acres. Combined with the amount of area covered by the waste piles, there are presently approximately 32 acres of bottom area affected by crab wastes.

The total bottom area of Unalaska Bay south of Hog Island is about 3.5 miles square or 2,240 acres. Thus, at present, crab wastes discharged on the west side of Amaknak Island directly influence approximately 1.4 percent of the benthic environment.

ALTERNATIVE DISPOSAL SYSTEMS

ENVIRONMENTAL EFFECTS OF DEEPWATER DISPOSAL OF CRAB WASTES

One of the alternatives to current crab waste disposal practices in Dutch Harbor is to screen the processing wastewater stream to separate the solid and liquid portions of the effluent and then barge the solid wastes to a deepwater disposal site. This alternative is one that has been often suggested by EPA. The proposed disposal site is in relatively open water off the northeast coast of Amaknak Island in about 300 feet of water. The effects of such an operation on water quality and marine biota in the disposal area are addressed here. Physical aspects of a barging operation are discussed by Brown and Caldwell (1979).

As the barging alternative is understood, there would be no grinding of wastes as is now practiced. Whole carapaces, tails, viscera, gills, and leg shells, if meat is extracted, would be dumped from a hopper barge instantaneously while being towed over the disposal site. Any residual liquids associated with the waste would disperse in the surface waters immediately upon dumping. The viscera, gills, and other soft-tissue fragments would tend to disperse or sink slowly in the surface waters since the density of these materials is only slightly greater than that of cold seawater. Eventual sinking could be expected, but time and location of sinking would depend on water column density stratification, prevailing winds, currents, and wave action. Some of these soft tissues could also be expected to be consumed by seabirds and fish. The more dense shell material would be expected to sink almost straight down and settle on the bottom. Brown and Caldwell (1979) estimated that the extent of bottom area covered by each barge load would be about 31,400 square feet (a 200-foot-diameter circle) at an average depth of 1.5 inches. Except for some turbidity generated during the dumping process, it is not anticipated that this type of operation would cause any adverse water quality or biological effects in the water column.

As is the case with the current discharge of ground wastes in nearshore waters, the water quality and biological effects of the dumped wastes will be manifest on the bottom. Deepwater disposal removes a major dispersive force identified as being responsible for waste dispersion in shallow waters, i.e., wave action and wave-generated bottom currents. At 300 feet, little dispersion can be expected. Furthermore, since the disposal area is relatively flat, little waste movement of any kind can be expected after initial settling.

The amount of bottom in the disposal area that would be covered with wastes annually was estimated by Brown and Caldwell (1979) to be 134 acres assuming that no new waste load overlapped previously dumped wastes. In contrast, an estimate of 32 acres has been made for the amount of bottom area affected by wastes discharged through outfalls by five processors in nearshore areas on the west side of Amaknak Island. Because pinpoint navigation and good weather conditions cannot be expected for each and every dump, there is a high probability that any particular dump would impact an area not previously affected by wastes, thereby incrementally increasing the amount of sediment covered. It is possible that some new areas could be impacted each season as opposed to the apparent steady-state condition that now exists on the west side of Amaknak Island.

There is no question that disposal of wastes in deepwater would preclude the large pile buildup experienced adjacent to most nearshore outfalls. However, wastes of even a few inches in depth have been observed to totally eliminate attached and burrowing organisms. In addition, there is no information on the extent of utilization of the proposed dumpsite by crabs and bottom fish. Thus, some impact to a commercial bottom fishery cannot be ruled out.

Even though the waste deposits are not expected to be exceptionally deep, the probability of anaerobic conditions occurring under the surface of the deposited wastes is high since the circulation of overlying waters will be less than in nearshore waters. Also, in areas about 300 feet deep around Dutch Harbor unaffected by crab wastes, dissolved oxygen concentrations 2 to 3 mg/l lower than shallower waters have been observed (Feder and Burrell 1978; Colonell and Reeburgh, 1978). Occurrence of anaerobic conditions can result in the production of sulfide as a consequence of waste degradation. Toxic concentrations of H_2S can be reached in the waste deposit interstitial waters and then diffuse into overlying waters. If water exchange rates over the waste deposits are slow, concentrations will remain high relatively longer than in nearshore waters. Since the wastes will not be ground before disposal, the degradation process of a given volume of waste will take longer. Longer degradation periods will result in the oxygen consumption and sulfide production processes also occurring over longer periods of time (see discussion of crab shell degradation rates in Brown and Caldwell 1978).

Several studies by EPA and the University of Alaska offer rather conclusive evidence of the detrimental effects of crab waste disposal into the confined basins of Dutch Harbor and Iliuliuk Harbor. It is not being suggested that a deepwater site would develop bottom characteristics identical to these confined harbors, but environmental characteristics such as current velocities, dissolved oxygen concentrations, and nutrient concentrations may be more similar between the harbors and the deepwater site than between the current nearshore disposal areas and the deepwater site.

In addition to the expected disposal site problems associated with the barging alternative, there is the potential problem of waste spillage and accumulation in the inner harbor loading areas. The total amount of waste spilled during a processing season is not expected to be large. Settleable solids would not significantly affect the existing poor sediment and bottom water quality conditions in the inner harbors. However, one could expect to see floatables and the liquid effluent dispersing from the barge during loading operations. This would probably be more of an aesthetic problem than a long-term detriment to overall water quality.

Although a good deal of conjecture and supposition has been presented in the preceding discussion, it appears that deepwater disposal does not provide any substantial water quality and marine biological benefits compared to current waste disposal practices. In fact, there may be some disadvantages with respect to a slower degradation process and a greater amount of bottom area covered with crab wastes.

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BENTHIC MACROFAUNA, SEDIMENT AND WATER QUALITY NEAR SEAFOOD CANNERY OUTFALLS IN KENAI AND CORDOVA, ALASKA

Final Report

February 15, 1979

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Abstract

Hydrological conditions, sediment and water quality, and macrobenthos, were examined at two Alaskan coastal sites in an effort to identify the ecological impacts which result from seafood processing operations. Monitoring studies were performed at Kenai and Cordova, Alaska, two sites not previously studied.

At Kenai, the impacts of cannery discharges on the marine environment were negligible. Little, if any, impact to water and sediment quality were observed. A poorly developed macrobenthos community was identified. However, this community structure appeared to result from natural rather than man-induced conditions. Tidal induced scouring and burial by bottom sediments, and daily salinity changes appeared to be the major factors which limited habitat utilization by macrobenthic organisms. Strong river and tidal currents flush the cannery discharge areas on a daily basis and problems of persistent seafood processing waste accumulations were not observed.

At Cordova, poor flushing action in the vicinity of active cannery outfalls had resulted in considerable accumulations of nonground processing waste debris at two of the three active discharge areas. Localized impacts to sediment and water quality, and surface water aesthetics in the vicinity of the disposal areas were also recorded. The macrobenthic community was generally stable and very diverse. The effects of cannery effluents on the macrobenthos were only observed at one of the active cannery outfalls. At this one outfall, considerable reduction in species richness and diversity occurred.

INTRODUCTION

On December 27, 1977, the Clean Water Act of 1977 was adopted to amend several provisions of the Federal Water Pollution Control Act Amendments of 1972. Section 74 of the new Act requires the U.S. Environmental Protection Agency (EPA) to conduct a study "to determine the effects of seafood processes which dispose of untreated natural wastes into marine waters, to examine technologies to facilitate the use of nutrients in these wastes or to reduce their discharge into the marine environment (1)". One aspect of the EPA study was to assess the geographical, hydrological, and biological characteristics of marine waters receiving untreated seafood processing waste discharges. The following report discusses this aspect for two seafood processing sites in Kenai and Cordova, Alaska.

Alaska is the location of numerous seafood processing facilities which utilize raw seafood catch in the preparation of finished products. Generally, a large portion of the raw material processed at these facilities is not utilized in the finished product. The percentage of unused or waste material varies with the species processed. In salmon processing, this waste material constitutes from 33 to 45 percent of the raw product (by weight), and from 36 to 88 percent in crab processing (2).

Although the unused raw product contains large amounts of protein and nutrients, Alaskan processing facilities usually discharge this material directly to receiving waters after little or no treatment. In recent years, attention has been directed at assessing the ecological effects (either beneficial or adverse) which result from these waste discharges. Both the seafood industry and the EPA have funded research in Alaska to study the effects of seafood processing at various sites. The following paragraphs discuss the results of these efforts.

REVIEW OF PREVIOUS ALASKAN STUDIES

In 1970, a preliminary ecological survey of Bristol Bay and Kodiak Island, Alaska, was performed by the Fisheries Research Institute of the University of Washington, Seattle, Washington (3). This study was in response to concerns expressed by the Northwest Canning Industry about the impact of seafood processing wastes on the receiving waters in the vicinity of salmon canneries. These investigations indicated no serious or significant detrimental effect on the ecology of marine organisms, although the wastes did cause some small depressions of dissolved oxygen at the surface and bottom in small, highly localized areas near the points of discharge (3, 4). These studies further noted that the depressions were not only highly confined, but were also very transient because of the twice-daily scouring and flushing effect of the tides. During the surveys at these two sites, sufficient amounts of oxygen for the healthy maintenance and growth of organisms were reported to be present at all times. Similar results at seven processing sites in British Columbia were reported from studies performed for the British Columbia Fisheries Association (5).

A brief water quality survey conducted by the University of Alaska in Dutch Harbor, Alaska, in 1968 (cited in 6) observed higher than normal concentrations of ammonia, and lowered dissolved oxygen resulting from the decomposition of accumulated seafood wastes on the bottom.

Brickell and Goering (7) reported large concentrations of ammonium and considerable oxygen depletion in the receiving waters of Iliuliuk Bay, Dutch Harbor, Alaska, as a result of canning activity. They concluded that the decomposition of seafood material, in a restricted body of water like the bay, could significantly influence the nitrogen concentration and availability in this environment, and some of the higher concentrations might affect marine organisms. They reported concentrations in the bay as high as 23.8 μg-atom NH_4^+-N/ℓ, while lower concentrations, although still higher than ambient levels, were observed over tens of square miles of ocean in the area. Open ocean ambient concentrations of ammonium were reported at 1 μg-atom NH_4^+-N/ℓ.

In addition to their work at Iliuliuk Bay, Brickell and Goering examined two other systems; a freshwater stream where salmon spawning occurred, and the receiving estuary where salmon carcasses accumulated following spawning. Their purpose in studying these systems was to evaluate a naturally occurring situation which showed accumulations of organic material in the marine environment similar to the situation observed in the vicinity of seafood procesing sites. They found that combined dissolved organic nitrogen and ammonium values in the natural systems approximated ammonium values in Iliuliuk Bay. These results suggested that high concentrations of ammonium and organic nitrogen from salmon decomposition may not be restricted to waters receiving wastes from seafood processing (7). Their results also indicated that dissolved organic nitrogen was the initial breakdown product of salmon decomposition.

Surveys in 1975 and 1976 by U.S. EPA (6) in Iliuliuk Harbor, Inner Iliuliuk Bay, and Dutch Harbor, Alaska, encountered low dissolved oxygen concentrations near the bottom, increased nutrient concentrations within the bays, and decomposing sludge deposits of seafood wastes. They attributed these conditions to large amounts of waste discharges which were not adequately dispersed due to poor current movement and circulation patterns.

Investigations of seven disposal locations used by seafood processors at Dutch Harbor, Alaska, during October 1976 and September 1977, found that, although some shellfish wastes were dispersed by tides, wave surges, and longshore currents, as well as being fed upon by aquatic organisms, the reduction of the waste material by these means and by decomposition was not as great as the rate of waste accumulation from the discharges (9). This research also recorded adverse impacts of the waste sludge beds on the benthic environment. The shellfish debris physically smothered all immobile organisms within a 30 m radius of the discharge point (8). Benthic communities on the periphery of the disposal site showed significantly fewer organisms than were present in control areas.

In 1971, EPA Region X reported on the pollution problem from shellfish processor discharges in Kodiak Harbor, St. Paul Harbor, and Gibson Cove, Alaska (9). These three embayments receive seafood processing wastes from 15 processing plants in or near the city of Kodiak. This area represents the greatest concentration of seafood processing plants in the state. In this study, Provant, et al. (9), observed oxygen concentrations of less than 6 mg/ℓ (with some surface-level concentrations as low as 1.3 mg/ℓ), and seafood solids accumulation on the bottom forming large sludge-like deposits. They estimated a bottom area of roughly 21 hectares (52 acres) to be severely impacted. Normal benthic marine life was not observed in this impacted area. Benthic samples obtained near processor outfalls did not contain any macroscopic forms, while samples collected further out from the outfalls contained only ooze-dwelling polychaetes and amphipods. The authors commented that the occurrence of these benthic organisms attested to the severely polluted bottom conditions. Sulfide concentrations in the water were reported to be at levels which might affect the ecological balance of the waters, or cause acute or chronic problems for marine organisms.

In 1971, the National Canners Association (presently National Food Processors Association) and Petersburg Fisheries funded a study to evaluate the impacts of seafood disposal by canneries in Petersburg, Alaska (10). The findings of this study indicated that cannery wastes did not appreciably affect dissolved oxygen concentrations; populations of intertidal fauna were abundant through the study area; scavenging fish and birds fed heavily on wastes from the discharge plume; and other water quality determinations demonstrated rapid dilution and dispersion of wastes.

Laboratory studies by Nakatani and Beyer (11), assessing the effects of salmon cannery waste on juvenile salmon, demonstrated that prolonged periods of exposure were required for these wastes to cause mortalities in selected juvenile salmonids. Initial mortalities, even at 20,000 ppm of salmon processing wastes (70 percent of peak discharge concentrations reported by Nakatani and Beyer (10) for Petersburg, Alaska), did not occur until after 20 hr of exposure, well beyond the time of a total tide cycle (11). Additional screening bioassays of the salmon waste indicated that the factor causing mortalities in the juvenile salmon was in solution rather than associated with particulate waste (11).

PURPOSE OF PRESENT STUDY

As indicated in the above discussion, the discharge of seafood processing wastes has been shown to cause varying impacts under different hydrological conditions. The present study is intended to identify the important site-specific factors which may determine the nature of the ecological impacts which result from seafood processing operations.

This study examined the marine environment near seafood cannery outfalls in Kenai and Cordova, Alaska, two Alaskan sites not previously studied. These sites differ with respect to hydrological conditions, seafood processed, and length of processing season.

The major areas of investigation in this study were:

- Aesthetic conditions, e.g. visible conditions in the water and along the shore
- Waste accumulations on the ocean bottom
- Hydrological conditions (tides and currents)
- Water and sediment quality
- Macrobenthos

MATERIALS AND METHODS

GENERAL DESCRIPTION OF STUDY AREAS

Field studies were conducted from July 23 to August 2, 1978, at Kenai and Cordova, Alaska. Kenai as sampled during the period July 23 to 27, and Cordova July 29 to August 2. Discussions with Alaskan Fish and Game and Alaskan cannery personnel in May and June, 1978, indicated that peak salmon runs and processing periods for Kenai and Cordova would probably occur during mid to late July for Kenai, and late July to early August for Cordova. Field sampling periods were selected to coincide as closely as possible with those projected peak processing times. The M/V Tres Cher, chartered out of Tacoma, Washington, was used to transport personnel and equipment to and from the sampling stations and study sites. When conditions permitted, some water quality sampling of shallow water stations was performed from a small skiff.

Kenai is located approximately 113 km (70 mi) south-southwest of Anchorage, Alaska, on the western side of the Kenai Peninsula (60° 33' N latitude, 151° 14' W Longitude) (Figure 1). Four canneries are located along the Kenai River and all discharge their processing wastes directly to the river. The two largest processors are Kenai Packers (KP), located nearest the mouth of the river, and Columbia-Wards Fisheries (CWF), located furthest upstream. The respective locations of these

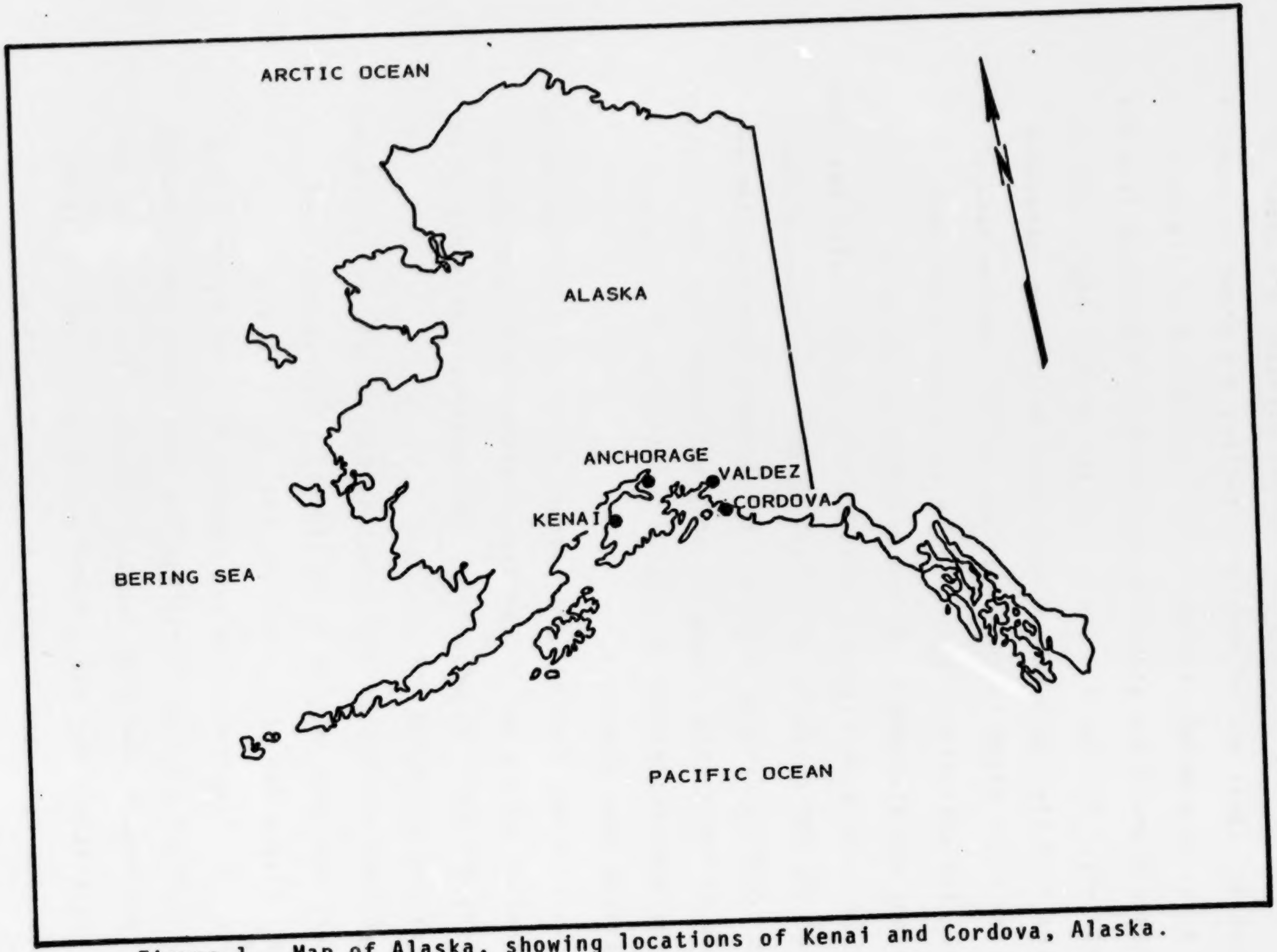

ARCTIC OCEAN
ALASKA
ANCHORAGE
VALDEZ
CORDOVA
KENAI
BERING SEA
PACIFIC OCEAN
N

Figure 1. Map of Alaska, showing locations of Kenai and Cordova, Alaska.

two canneries and of the general areas surveyed are shown in Figure 2. Locations of sampling stations are shown in Insets A and B for KP and CWF, respectively. In Inset A of Figure 2, Stations A and X are shown located furthest downstream from the KP cannery. Station B', located at the outfall pipe, receives wastes from the egghouse and mechanical butchering operations. Station C' is shown located near the outfall for the hand butchering operation. Station E is the furthest upstream station, and Stations L, M, and N served as controls.

In Inset B of Figure 2, Station S is shown located near the end of the CWF outfall. Officials at CWF were unsure of its exact location because they were not present when the line was relaid in the spring. However, they estimated that its location was the area designated by Station S. Station R is located downstream from Station S.

Large tidal fluctuations, strong river and tidal currents, and shallow waters and hidden shoals prevented more extensive sampling off CWF. Consequently, the heaviest concentration of samples was collected off KP.

Cordova is located approximately 257 km (160 mi) southeast of Anchorage, and roughly 80 km (50 mi) south-southeast of Valdez, Alaska (60° 33' latitude; 145° 66' W longitude) (Figure 1). Four canneries are located in Cordova; St. Elias Ocean Products (St. E), North Pacific Processors (NPP), Morpac, Inc., and New England Fish Company (NEFCO). The locations of sampling stations for the Cordova survey are shown in Figure 3. Stations N, O, and P served as control stations.

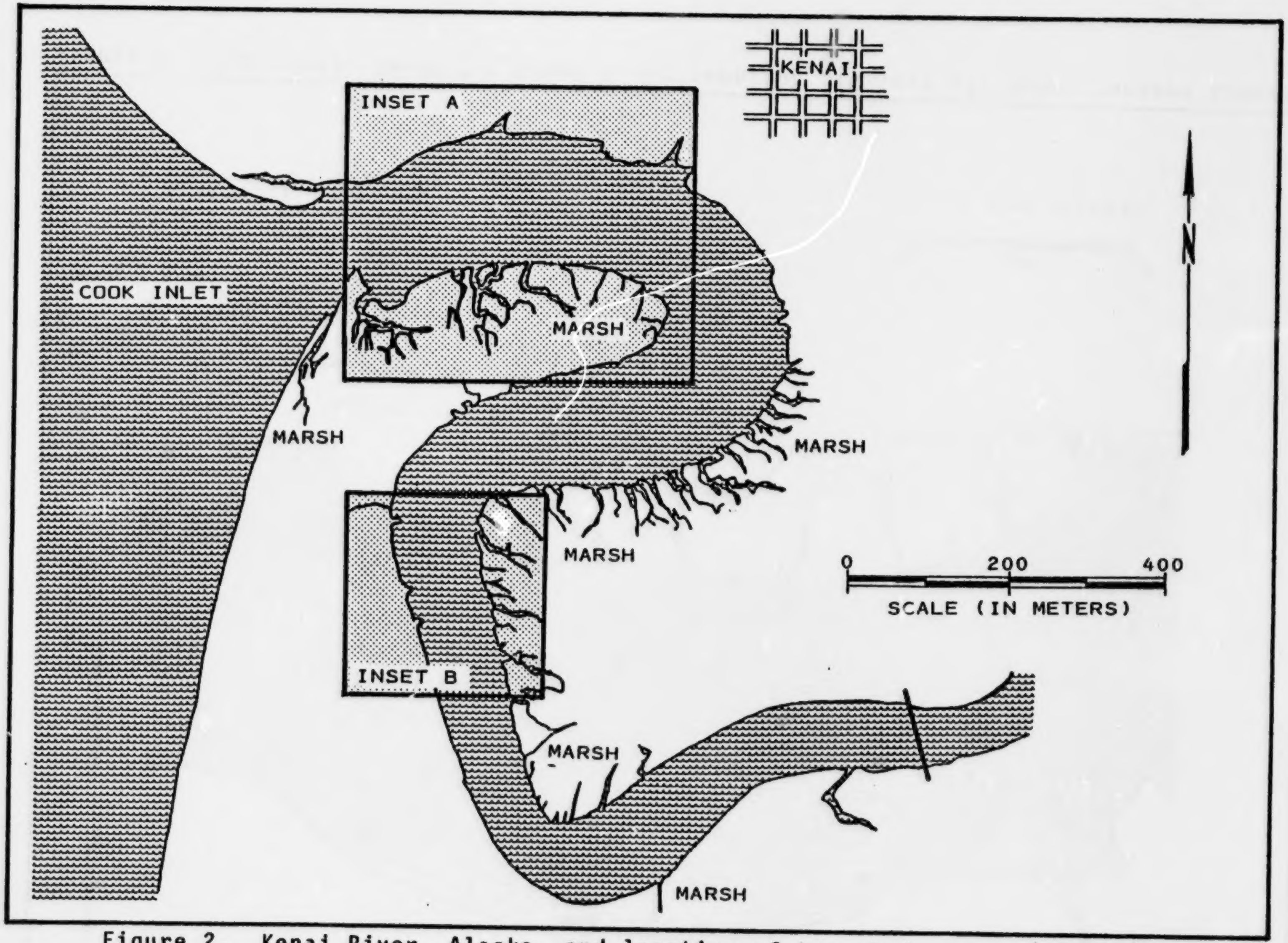

KENAI
INSET A
INSET B
COOK INLET
MARSH
MARSH
MARSH
MARSH
MARSH
MARSH
N
0
200
400
SCALE (IN METERS)

Figure 2. Kenai River, Alaska, and location of two study zones (Insets).

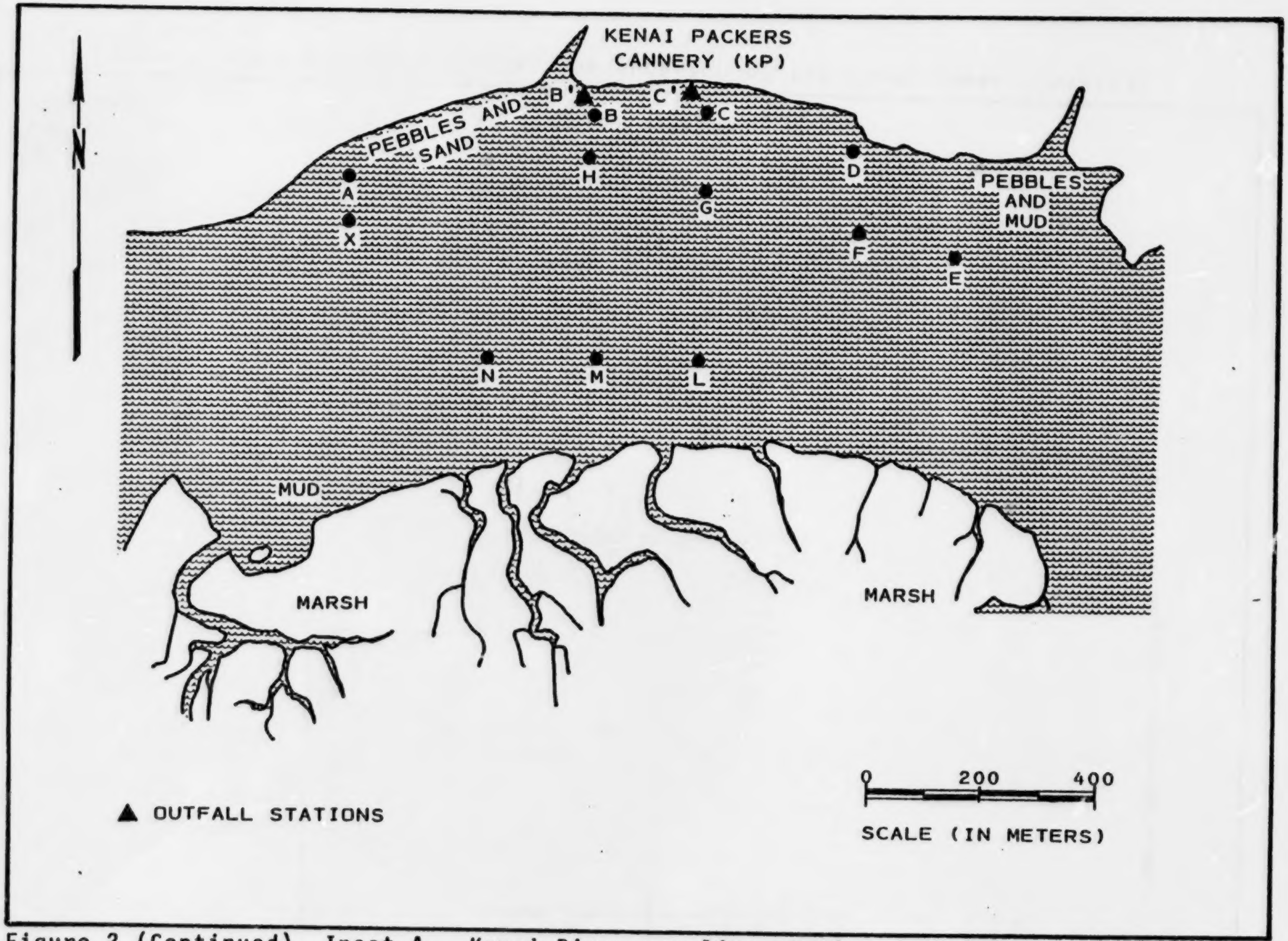

N
KENAI PACKERS CANNERY (KP)
B'
C'
PEBBLES AND SAND
PEBBLES AND MUD
A
X
B
C
H
D
G
F
E
N
M
L
MUD
MARSH
MARSH
▲ OUTFALL STATIONS
0
200
400
SCALE (IN METERS)

Figure 2 (Continued), Inset A. Kenai River sampling stations off Kenai Packers Cannery.

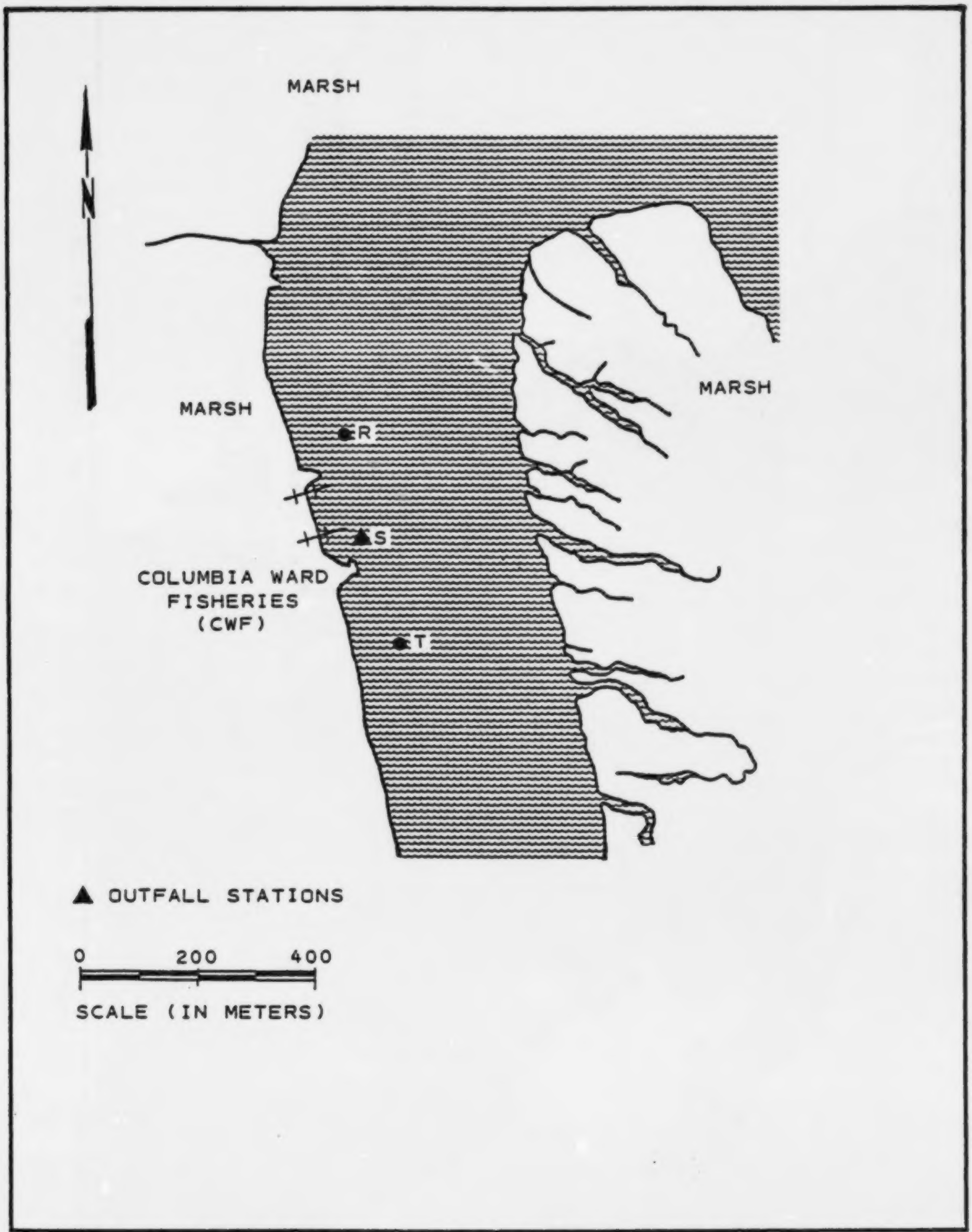
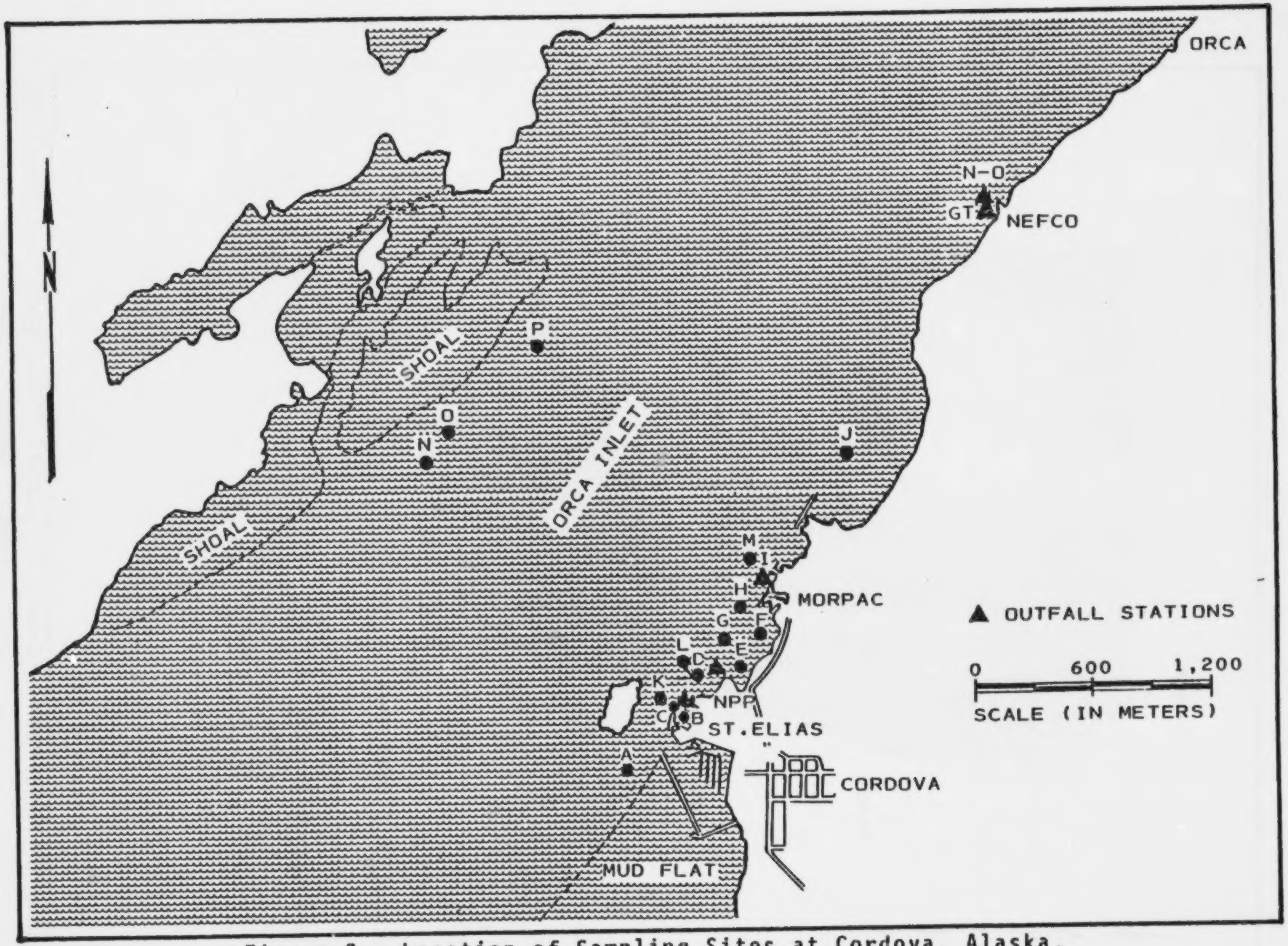

MARSH
N
MARSH
MARSH
R
S
T
COLUMBIA WARD
FISHERIES
(CWF)
▲ OUTFALL STATIONS
0
200
400
SCALE (IN METERS)

Figure 2 (Continued), Inset B. Kenai River sampling stations off Columbia Ward Fisheries.



ORCA
N-O
GT
NEFCO
N
SHOAL
P
O
N
ORCA INLET
SHOAL
J
M
I
H
MORPAC
G
F
L
D
E
K
NPP
C
B
ST.ELIAS
A
CORDOVA
MUD FLAT
▲ OUTFALL STATIONS
0
600
1,200
SCALE (IN METERS)

Figure 3. Location of Sampling Sites at Cordova, Alaska.

HYDROLOGICAL DETERMINATIONS

Daily tidal range and tidal currents for the two sites were calculated using National Oceanic and Atmospheric Administration (NOAA) Tide Tables 1978 (12) and Tidal Current Tables 1978 (13). These tables list high and low water predictions for the Kenai City Wharf (located less than 1 km upstream of KP), tidal currents for the KP Wharf, tidal height for Cordova Harbor, and mid-channel tidal current predictions off Cordova. Field current measurements were not made because of equipment malfunctions.

WATER QUALITY

Water quality was determined by measurement of the following parameters: dissolved oxygen, temperature, salinity, transparency, pH, ammonia, organic (Kjeldahl) nitrogen, orthophosphate, total phosphorus, and hydrogen sulfide.

Water samples for salinity, dissolved oxygen, pH, and nutrients were collected with a 3 ℓ, opaque, Van Doren water sampler at bottom, mid- and surface water depths. Duplicate samples were obtained for each depth.

Nutrient and hydrogen sulfide analyses were made by Dames and Moore Engineering, Fairbanks, Alaska, after the methods described in Standard Methods (14) and U.S. EPA Methods for Chemical Analysis of Water and Wastes (15).

Dissolved oxygen was measured by a Modified Winkler procedure (16); temperature with a stem thermometer (0.1°C); salinity with an American Optical refractometer (0.2‰), Model No. 10419; transparency with a white Secchi disc (15 cm diameter); and pH with an Orion field pH meter, Model No. 339A.

SEDIMENT SAMPLES

Four sediment samples were collected at each station using a 0.1 m^2 Van Veen benthic bottom sampler. At Kenai, benthic samples from stations exposed during low tide were obtained using a rectangular plastic sampler measuring 0.1 m^2. For the latter method, the sample area was randomly selected and the sampler pushed into the sediment. The material within the sample area was removed to a maximum depth of 16 cm (6 in).

Two of the four sediment samples were used intact for benthic faunal analysis. These benthic samples were transferred to 5-gal plastic buckets, fixed immediately with a 10 percent buffered formalin solution, sealed, and shipped to the University of Alaska, Sorting Center, Seward, Alaska, for sorting and identification of benthic organisms. At the Sorting Center, the samples were deformalized using diluted ammonia and then washed on a 1 mm screen. The material retained was represerved in 10 percent buffered formalin. The material which passed through the 1 mm screen was retained and washed again on a 0.5 mm screen.

The 1 mm screen material was placed on a dark green and white tray in water. The material was examined on first the dark, and then the light side of the tray. The organisms removed were again preserved for later identification.

The material retained on the 0.5 mm screen was drained. A pie shaped slice was removed for sorting and identification. Total 0.5 mm sample weight and weight of each fraction were determined. The numerical values for the organisms identified in the sample fraction were corrected to the total weight of the sample.

Three 500 ml plastic screw-cap jars were filled from each of the remaining two sediment samples for sediment chemistry analysis. Total organic carbon (TOC), total volatile solids (TVS), total Kjeldahl nitrogen (TKN), and total sulfide (TS) determinations on two of the three sub-samples were conducted by the Analytical Research Laboratory at University of Southern California, Los Angeles, California. Procedures described in Standard Methods (14) were used for TKN, TVS, and TS. TOC determinations were made on 5 g of wet sediment using a LECO TC-12 Automatic Carbon Analyzer. Particle size distribution studies on the third sub-sample were determined by SCS Engineers, Long Beach, after methods described in American Standards for Testing and Materials (17).

UNDERWATER PHOTOGRAPHY

Underwater video films were taken at Cordova for indications of seafood processing waste accumulations and responses by marine organisms to these wastes. Bottom conditions at each cannery outfall, at mid-channel stations, and control sites were recorded. Similar filming at Kenai was not performed because of highly turbid river waters and strong currents.

BIOLOGICAL INDICES

Faunal density at each station was calculated as the total number of individuals of all species (N). Species richness was estimated as the number of species (S) collected at each station Species diversity was calculated according to the Shannon-Wiener formula:

$$H' = \Sigma P_i \ln P_i \quad (18)$$

where $P_i = n_i/N$; P_i = proportion of total number of individuals occurring in species i.

Normal numerical classification of the benthic data was also performed. The normal classification grouped the stations according to species similarities, and the species acording to station similarities. The Czekanowski coefficient (19, 10) was used in the normal classification, and was calculated as follows:

$$C_Z = 2W/(A + B)$$

where:

A is the sum of the species scores for sample a;

B is the sum of species scores for sample b;

W is the sum of the smaller scores of each species in the two samples being compared.

All species counts were log transformed using log (X + 1) (20). After the formation of a matrix of coefficients, a dendrogram was produced using group-average sorting (21).

Species represented by five or less individuals in all benthic samples from a given location were not included in the statistical analyses of benthic macrofaunal data. While it has been argued that the elimination of rare species may remove those species which are highly selective in their habitat type, it has been shown by Field (19) and Day, et al. (22) that rare species have virtually no effect on community structure analysis when using the Czekanowski coefficient of similarity. After the initial data reduction, replicate samples from each station were pooled for quantitiative faunal analysis.

LIMITATIONS TO SAMPLING

At Kenai, strong tidal currents confined all sampling to the slack water period. The slack following the maximum flood usually afforded the most time for sample collections (1-2 hr). As tidal currents increased, severe problems with the wire angle of water bottle and benthic grab lines were encountered, thus preventing collection of meaningful samples. Tidal currents at Cordova were not a hindrance to sample collection.

Limitations imposed by field conditions, available field sampling time, and in-lab sample processing time, prohibited any additional sampling or resampling of stations or sites.

RESULTS AND DISCUSSION

KENAI

Description of Seafood Processing Operations

Salmon and herring processing at Kenai occurs from mid-May through mid-August. Processing of canned and frozen salmon products occurs from late June through mid-August at both KP and CWF. Herring processing at both canneries is limited to mid-May.

Estimated seafood waste production quantities for these two Kenai canneries are shown by seafood type in Tables 1 and 2. As indicated in these tables, over 1,200 and 1,500 Tons of processing wastes were produced and discharged to the Kenai River by KP and CWF, respectively, in 1977. Waste production figures for the 1978 season were not available; however, it is anticipated that 1978 waste production figures will exceed those of 1977 because of record salmon catches for the 1978 season.

Field monitoring studies at Kenai were performed approximately one week after the peak cannery processing period, although considerable processing activity was ongoing during the field sampling.

Aesthetic Conditions

At KP, discoloration of surface waters and accumulations of nonground fish parts (heads, fins, viscera, and roe) were observed at one discharge point (Station B') during periods of

TABLE 1

ESTIMATED SEAFOOD WASTE PRODUCTION KENAI PACKERS *

Type of Waste	Waste Quantity (Tons/year)		
	1977	1976	1975
Salmon	1,290	994	666
Tanner Crab	-	-	-
Dungeness Crab	-	-	-
Halibut	-	-	-
Herring	-	104	109

TABLE 2

ESTIMATED SEAFOOD WASTE PRODUCTION COLUMBIA-WARDS FISHERIES*

Type of Waste	Waste Quantity (Tons/year)		
	1977	1976	1975
Salmon	1,550	1,560	717
Tanner Crab	-	-	-
Dungeness Crab	-	-	-
Halibut	-	-	0.6
Herring	-	101	-

*Ref. 23

slack low water. At this discharge point, wastes were being discharged above the low-tide level, resulting in pinkish surface discolorations and whole-fish waste accumulations on shore near the discharge (Figure 4). According to KP Cannery officials, whole, ~~non~~unground wastes were being discharged because the grinder was inoperative. These effects were limited to an area of riverbank and adjacent littoral region 15 m downstream from the discharge at low tide. Beyond 15 m, currents sufficiently diluted the surface discolorations. The combined action of currents and tidal fluctuations removed the accumulated fish wastes to the extent that the shore was clean by ~~the~~ low tide ~~of~~ the following morning. Sediment samples and general observations of river margins further downstream (Stations A and X) did not indicate the presence of any fish parts. The extent, if any, of upstream transport of these wastes during flood tides was not investigated.

No surface effluent plume or fish wastes were observed at or near Station C' (hand butchering outfall). However, a waste stream was apparent through portions of the dock-face, resulting in the discoloration of the waters immediately adjacent to the dock-face near the egghouse at slack waters of low-tide, and in the accumulation of waste materials on the exposed riverbank portions at the base of the wharf. The origin of this waste stream was not apparent, since the entire understructure of the wharf is concealed by exterior siding. According to cannery personnel, however, a waste collection line does run under the

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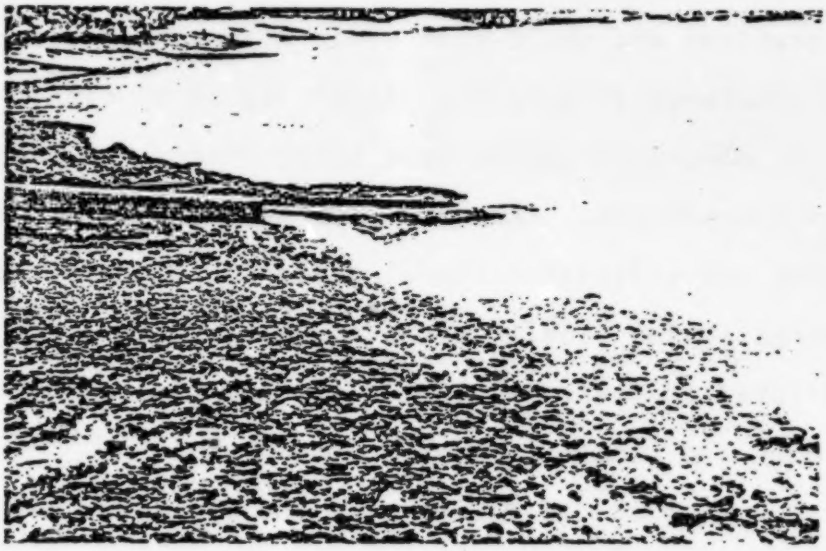
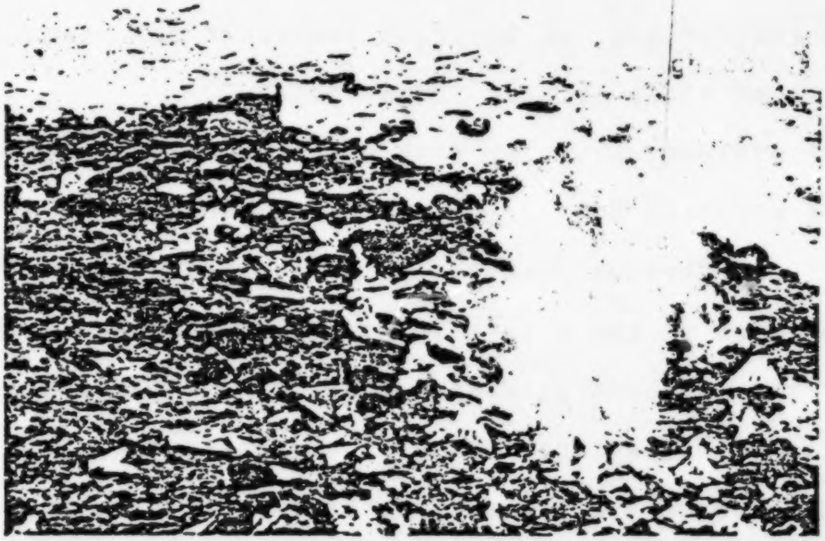


4a. Seafood processing waste stream discharged above low water level.



4b. Accumulations of whole fish parts on Kenai River bank immediately downstream of cannery outfall.

Figure 4. Evidence of seafood waste accumulations near Kenai Packers Cannery outfall.

wharf from the mechanical-butchering area connecting into the egghouse discharge line and leaks in this line may have been the source of the dock-face waste stream. As in the case of the waste accumulations at Station B', changes in tidal height and currents removed these accumulations and diluted surface discolorations on a daily basis.

At CWF, the grinder system was in operation during the field sampling, and no surface discolorations, or floating debris, were observed near the CWF sampling stations.

Decreases in water transparency as the result of cannery discharges were not assessed because of naturally high concentrations of suspended material, primarily glacial fines, in the Kenai River.

Bottom Accumulations

Underwater photography was not performed at Kenai because water transparency was severely limited by high concentrations of suspended glacial fines.

Hydrological Conditions

Tidal height data for Kenai is presented in Table 3. As indicated in this table maximum diurnal tidal ranges of 8.1 m were encountered at Kenai. The extent of diurnal variation in tidal height at KP Wharf are shown in Figure 5. Figure 5a indicates tidal height on July 25 near maximum flood tide and Figure 5b during ebb tide. Tidal current data for the Kenai River at the KP Wharf is listed in Table 4.

TABLE 3 . TIDAL DATA FOR KENAI, ALASKA
JULY 23-JULY 26, 1978*

Date	LW	HW	LW	HW	Maximum Diurnal Range
	meters (feet)				
July 23	-0.3 (-1.0)	6.9 (22.8)	-1.2 (-3.9)	6.8 (22.4)	8.1 (26.7)
July 24	-0.2 (-0.5)	6.5 (21.3)	-0.6 (-2.1)	6.6 (21.5)	7.2 (23.6)
July 25	0.1 (0.3)	5.9 (19.4)	0.0 (0.0)	6.2 (20.3)	6.2 (20.4)
July 26	0.4 (1.3)	5.3 (17.5)	0.7 (2.3)	5.8 (19.0)	5.4 (17.7)

*Ref. 13

Legend: LW = Low Water
HW = High Water

TABLE 4. TIDAL CURRENT DATA FOR KENAI, ALASKA JULY 23-JULY 26, 1978*

	Maximum Tidal Current			
	Flood	Ebb	Flood	Ebb
Date	In km/hr (knots)			
July 23	1.9 (1.0)	4.1 (2.2)	2.0 (1.1)	3.3 (1.8)
July 24	1.7 (0.9)	3.5 (1.9)	3.2 (1.7)	1.7 (0.9)
July 25	1.5 (0.8)	2.8 (1.5)	1.5 (0.8)	2.6 (1.4)
July 26	1.1 (0.6)	2.2 (1.2)	1.3 (0.7)	2.4 (1.3)

*Ref. 14

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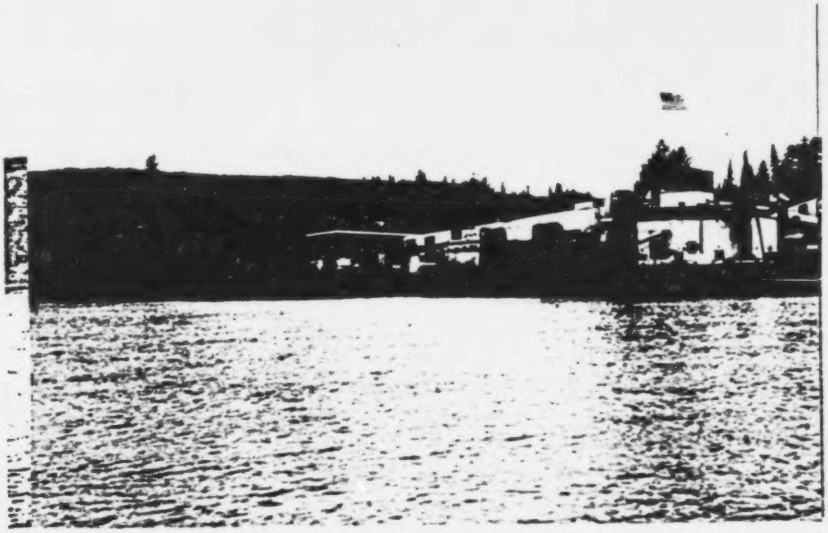
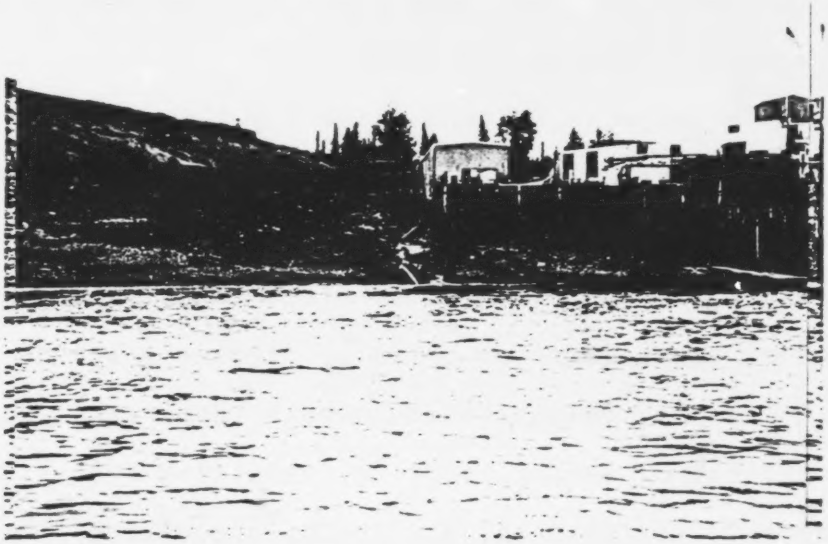


5a. Tidal height off Kenai Packers near maximum flood tide.



5b. Tidal height off Kenai Packers during ebb tide.

Figure 5. Variations in tidal height at Kenai Packers Cannery, Kenai, Alaska.

The combined action of tidal currents and large daily variations in tidal height appeared to sufficiently flush the Kenai River of seafood processing wastes. As discussed in an earlier section, no persistent accumulations of processing wastes were observed. Wastes which did accumulate on shore near one KP outfall and below the KP wharf at low tide were removed by the low tide of the next tidal cycle.

Water Quality

Water quality data for Kenai River sampling stations are presented in Table 5.

Surface dissolved oxygen values for all stations measured at or near saturation. The lowest oxygen measurement (8.5 mg/ℓ) was from bottom water at Station C. Values of 9.0 mg/ℓ or greater were typically observed, and there were no indications of depressed oxygen values at any station.

Variations in temperature were primarily a function of tidal cycle, the degree of mixing, density differences between brackish and fresh water, and sampling date. Some samples collected during slack water of ebb or flood tides showed no stratification of temperature or salinity. Other stations (e.g., E, F, X, and R), demonstrated inverse temperature and salinity stratification during sampling, resulting from tidal flow, water density differences, and incomplete mixing. Evidence of tidal cycle influence was shown at Stations G and H. Although these stations were sampled on the same date, sampling occurred during different portions of the tidal cycle.

TABLE 5. WATER QUALITY AND DEPTH FOR KENAI RIVER SAMPLING STATIONS.

		Station													
Parameter		A	B	B'	C	C'	D	E	F	G	H	X	R	S	T
Date (1978)		7/26	7/24	7/26	7/23	7/26	7/26	7/25	7/25	7/23	7/23	7/26	7/26	7/26	7/26
Time		1600	0600	1630	0650	1700	1500	0720	0750	1500	1430	0830	0900	0800	0720
Depth (m)		0.3	8.5	0.3	9.9	0.3	0.3	6.3	8.8	7.0	12	7.8	6.5	6.5	5.5
Dissolved Oxygen (mg/ℓ)	S	10.8	9.0	10.9	9.3	10.6	10.9	9.5	9.9	10.0	9.1	9.7	10.2	10.0	10.5
	M	--	9.0	--	9.0	--	--	9.1	9.0	10.1	8.9	9.0	9.5	10.2	10.5
	B	--	--	--	8.5	--	--	8.9	9.2	10.7	9.1	9.0	9.5	9.6	10.5
Temperature (°C)	S	12.4	12.4	12.3	12.0	13.0	12.4	12.0	11.6	11.1	12.7	11.6	12.0	12.0	11.9
	M	--	12.3	--	12.0	--	--	12.4	12.1	11.2	12.7	12.2	12.1	12.0	11.9
	B	--	12.3	--	12.0	--	--	12.4	12.2	11.2	12.7	12.2	12.2	12.1	11.9
Salinity (‰)	S	0.0	25	0.0	22.0	0.0	0.0	19.0	11.0	0.0	21.0	22.0	3.0	0.0	1.0
	M	--	26	--	24.0	--	--	22.0	21.0	0.0	24.0	24.0	12.0	0.0	0.0
	B	--	26	--	23.5	--	--	25.0	25.0	0.0	24.0	26.0	20.0	9.0	0.0
pH	S	6.6	7.3	6.6	8.1	6.6	6.5	7.6	7.4	6.4	6.8	7.9	6.7	6.5	6.7
	M	--	7.3	--	8.0	--	--	7.6	7.5	6.9	7.4	7.6	7.5	6.6	6.8
	B	--	7.4	--	8.1	--	--	7.7	7.6	7.3	7.7	7.7	7.6	7.4	6.6
Seechi Depth		--	0.23	--	0.20	--	--	--	--	0.20	--	--	--	--	--
Ammonia (mg/ℓ)	S	ND	ND	ND	0.04	0.04	ND	0.03	ND	<0.02	0.02	ND	ND	ND	ND
	M	--	ND	--	<0.02	--	--	ND	ND	ND	ND	ND	ND	ND	ND
	B	--	ND	--	0.02	--	--	ND	ND	<0.02	ND	0.02	ND	ND	ND
Organic Nitrogen (mg/ℓ)	S	0.03	0.10	0.03	0.08	0.04	0.03	0.04	0.03	0.02	0.03	0.04	0.02	0.03	0.02
	M	--	0.07	--	0.05	--	--	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.03
	B	--	0.05	--	0.06	--	--	0.03	0.05	0.03	0.02	0.03	0.02	0.02	0.02
Orthophosphate (mg/ℓ)	S	ND	0.03	ND	0.02	ND	ND	0.02	0.02	ND	0.03	0.02	ND	ND	ND
	M	--	0.03	--	0.03	--	--	0.03	0.03	ND	0.02	0.03	ND	ND	ND
	B	--	0.03	--	0.03	--	--	0.03	0.03	ND	0.02	0.03	ND	ND	ND
Total Phosphorus (mg/ℓ)	S	0.03	0.03	0.02	0.03	0.02	0.03	0.02	0.03	0.03	0.03	0.04	ND	ND	ND
	M	--	0.03	--	0.03	--	--	0.03	0.03	0.03	0.03	0.04	0.02	ND	ND
	B	--	0.03	--	0.04	--	--	0.03	0.03	0.02	0.02	0.05	ND	0.02	ND
Sulfide (mg/ℓ)	S	ND	ND	ND	ND	<0.004	ND	ND	ND	ND	ND	ND	ND	ND	ND
	M	--	ND	--	ND	--	--	ND	ND	ND	ND	0.004	ND	ND	ND
	B	--	ND	--	ND	--	--	ND	0.005	ND	ND	ND	ND	ND	ND

Salinity showed the most dramatic daily fluctuations of the parameters examined. Salinity values ranges from fresh water conditions (0.0‰) during ebb tides to brackish water concentrations (<26‰) during flood tides. This daily fluctuation was solely a function of tidal exchange, and any contribution from cannery discharges would have been negligible. The greatest range in daily fluctuations occurred at KP because of its closer proximity to saline ocean waters. Fluctuations of 12‰ were observed in the river off CWF.

Variations in pH between stations appeared to parallel salinity changes. Lower pH values (6.4-6.7) were observed during ebb tides, while higher pH values corresponded to flood tides.

The low secchi depth values resulted from the high concentrations of suspended glacial fines in the water. This suspended matter greatly reduced water transparency.

Nutrient concentrations were extremely low in the river water and in many instances were below or only slightly above minimum detection limits. Variations in nutrient concentrations between stations were not apparent with the possible exception of higher Kjeldahl nitrogen concentrations at Stations B and C. At the range of concentrations observed, these differences may not be important.

Sulfide values were generally below detection limits or at concentrations which were insignificant.

Sediment Particle Size

Sixteen stations were sampled for particle size distribution of Kenai River sediments. Particle size distributions for these stations are shown in Table 6. Substantial variation existed between stations, largely as a function of the river configuration, current, and sediment deposition patterns. In the narrower portions of the river off CWF (Stations R, S, and T), currents scour the bottom and carry away the finer sized material. Gravel and sand were characteristic of the sediment at these stations. As the channel curves downstream from CWF (Figure 2), the riverbank is eroded and some of the eroded material is carried downstream with the current. This material is deposited, in part, further downstream at Stations L, M, and N. Formation of eddies and bars as the river channel widens toward the mouth will also cause deposition of material along these features. Although these features are transient in nature, they may account for the high sand content observed at Stations E, F, and H. The riverbank, including the portion housing the KP cannery, is another point of erosion, and patchy, exposed areas of clay and sand were commonly observed along this stretch at low tide. Higher percentages of silt and clay were found in material collected along this portion of the river (Stations A, B', C', and D).

Sediment Chemistry

Results of sediment chemistry analyses for 16 stations in the Kenai River are shown in Table 7. Sediment chemistry was

TABLE 6. SIZE DISTRIBUTION (PERCENT WEIGHT) OF KENAI RIVER SEDIMENT SAMPLES.

	Station																
Size Class	A	B	B'	C	C'	D	E	F	G	H	L	M	N	X	R	S	T
Gravel*	5	-	0	50	9	28	6	7	96	8	2	0	4	30	35	93	42
Sand†	49	-	46	44	29	22	90	89	4	85	92	96	84	66	63	7	51
Silt#	29	-	32	4	34	28	4	4	0	2	2	1	7	4	2	0	5
Clay**	17	-	22	2	28	22	0	0	0	5	4	3	5	0	0	0	2

Legend

*Gravel - >2 mm
†Sand - 50 microns to 2 mm
#Silt - 2-50 microns
**Clay - >2 microns

TABLE 7. SEDIMENT CHEMISTRY DATA FOR KENAI RIVER SAMPLING STATIONS.

	Station															
	A	B	B'	C	C'	D	E	F	H	L	M	N	X	R	S*	T
Volatile Solids (%)	1.57	2.22	1.35	0.78	0.80	2.73	1.49	1.20	1.16	1.22	0.93	1.16	1.32	1.55	1.68	1.44
Total Organic Carbon (%)	0.245	0.282	0.34	0.07	0.33	0.32	0.097	0.096	0.07	0.064	0.060	0.091	0.092	0.105	0.110	0.06
Total Sulfide (mg/kg) (dry)	43.4	39.7	290	28.5	72.8	75.5	24.3	58.6	33.5	44.9	43.2	34.5	23.5	28.5	125.0	65.3
Total Kjeldahl Nitrogen (mg/kg) (dry)	107	98	100	46.6	123	68.6	26.3	390	74.6	92	45.3	46.2	30.1	26.3	30.6	46.9

*No replicate.

not performed on Station G sediment because of limited sample material. TVS content in the river sediment was low, with the highest values occurring at Stations B (2.22 percent) and D (2.73 percent). TVS content in outfall station sediments was among the lowest in value. Although TOC concentrations were highest at the two KP outfall stations (B' and C'), high TOC values were also measured at stations downstream (Station A), and upstream (Stations B and D) of the outfalls. At this time, it is not clear whether the higher TOC concentrations at Stations A, B', B, C', and D are the result of cannery discharges or naturally high TOC concentrations in the sediment at these stations. Stations C, L, M, and N had the lowest TOC values. TOC concentrations at Stations R and S were nearly twice the concentration at Station T. Although all three of the CWF stations had sediment that was predominantly sand and gravel, the higher TOC values at Station S and downstream at Station R, suggested the possible influence of cannery discharges on sediment TOC values at these stations. Total sulfide was highest at outfall Stations B' and S.

Macrobenthos

Sediment samples for benthic macrofaunal analysis were collected from all stations except B, C, and S. Adequate-size samples for benthic analysis could not be obtained at these stations despite repeated grab attempts. A list of the organisms found at each station in the 1 mm, 0.5 mm, and combined screenings are given in Tables 8, 9, and 10, respectively. Density and species richness values for the combined screening data are shown in Table 11.

The 1 mm screening data in Table 8 indicated that oligochetes and, to a lesser degree, gammarid amphipods were the only macrobenthic organisms occurring in significant numbers. The 0.5 mm screening data (Table 9), however, revealed the presence of two additional animal groups, nematodes and platyhelminths, with nematodes clearly the dominant species of the four groups. The appearance of nematodes and platyhelminths in the 0.5 mm screenings also demonstrated the importance of performing the 0.5 mm screening on benthic samples. The station occurrence, richness, and density of species had clearly changed from the conditions described by the 1.0 mm data. Without the 0.5 mm data, an inaccurate description of the benthic community in the Kenai River would have been made.

The combined macrobenthic data presented in Table 10 showed that nematodes and oligochaetes were the dominant macrobenthic species, with nematodes being the principal dominant. Nematode and oligochaete abundance was greatest in sediment with a high percentage of sand (e.g., Stations E, F, M, X, and R). Although these organisms were able to utilize a sand habitat, a sand habitat can also restrict colonization by some benthic organisms. Sediment with high sand content may exclude those

TABLE 8 STATION LIST OF MACROBENTHOS OF KENAI RIVER SEDIMENTS (1 mm SCREENINGS) *

	STATION													
	A	B'	C'	D	E	F	G	H	L	M	N	X	R	T
Gammaridae	0	0	0	0	0	0	0	0	0	0	0	1	2	14
Oligochaeta	0	0	0	4†	8	13	127†	173†	0	4	7	41	328	276

* Unless otherwise noted, abundance values represent mean of replicate samples.

† No replicate.

TABLE 9. STATION LIST OF MACROBENTHOS OF KENAI RIVER SEDIMENTS (0.5 mm SCREENINGS).*

	STATION													
	A	B'	C	D	E	F	G	H	L	M	N	X	R	T
Gammaridae	0	0	0	0	0	0	0	0	0	0	0	21	0	0
Oligochaeta	17	0	0	75$^+$	1,863	0	110$^+$	288$^+$	0	0	1,000	489	1,352	561
Nematoda	0	43	11	2$^+$	1,775	2,250	268$^+$	403$^+$	625	2,750	179	595	7,960	149
Platyhelminthes	0	0	0	0	0	0	0	0	0	250	0	0	0	82

* Unless otherwise noted, abundance values represent mean of replicate samples.

$^+$ No replicate.

TABLE 10. STATION LIST OF MACROBENTHOS OF KENAI RIVER SEDIMENTS (1 · AND 0.5 mm SCREENINGS)*

	STATION													
	A	B'	C'	D	E	F	G	H	L	M	N	X	R	T
Gammaridae	0	0	0	0	0	0	0	0	0	0	0	22	2	14
Oligochaeta	17	0	0	79[+]	1,863	13	237[+]	461[+]	0	4	1,007	530	1,680	837
Nematoda	0	43	11	2[+]	1,775	2,250	268[+]	403[+]	625	2,750	174	595	7,930	149
Platyhelminthes	0	0	0	0	0	0	0	0	0	250	0	0	0	82

* Unless otherwise noted, abundance values represent mean of replicate samples.

[+] No replicate.

TABLE 11. DENSITY (N), AND SPECIES RICHNESS (S) VALUES OF KENAI RIVER BENTHIC SAMPLES (COMBINED 1 AND 0.5 mm SCREENING DATA).

Station	N	S
A	17	1
B'	43	1
C'	11	1
D	81	2
E	3,638	2
F	2,263	2
G	505	2
H	864	2
L	625	1
M	3,004	3
N	1,181	2
X	1,147	3
R	9,612	3
T	1,082	4

benthic forms which require a less coarse sediment for tube building, or some organisms which are surface detrital and deposit feeders. The limitations imposed by a sandy habitat may explain the low species richness observed at these stations.

Species density, and species richness were greatest at Stations R and T, respectively. Daily salinity changes at these stations are less than at the other sampling stations, and this factor may make the sediment environment at Stations R and T more suitable to benthic organisms. Species density was greatest at Station R. Although this station is located downstream of CWF, without benthic samples from Station S and between Stations R and S, it cannot be concluded that the greater density was associated with CWF waste processing discharges.

Depauperate macrobenthic conditions were reported for Stations A, B', C', and D. At this time, it is not clear whether these conditions were the result of cannery discharges or were due to sediment type. Sediment clay content was highest at these stations, and this factor may have restricted habitat utilization by burrowing benthic forms. Some parameter not tested in this study may also have been responsible.

Community structure analyses of the Kenai River macrobenthos data were not performed because of the low number of species.

As a whole, the Kenai River benthic community is poorly developed. Attempts to associate cannery discharges to the observed benthic conditions were inconclusive. Limitations on habitat utilization imposed by sediment type, tidal induced scouring and burial by bottom sediments, and daily salinity changes are probably the major factors responsible for low species richness and the generally poorly developed benthic community.

Description of Seafood Processing Operations

Seafood processing at Cordova differs somewhat from Kenai. In addition to processing several salmon species, Tanner and Dungeness crab, halibut, and herring are also processed. Unlike Kenai, the seafood processing season at Cordova can run year-round. The actual length of the Cordova season is dependent upon the seafood catch. The salmon processing season typically runs from early July through mid-August. Dungeness crab processing runs from June through October, and Tanner crab from mid-November through June.

Estimated 1977 seafood waste production quantities are shown by seafood type in Tables 12, 13, and 14, for St. E, NPP, and NEFCO, respectively. Although written requests for waste production data were sent in September, 1978, to the home offices of all processing plants associated with the marine monitoring program (E. C. Jordan, personal communication), a response was not received from Morpac, Inc. For the years shown in Tables 12 and 13, crab processing wastes ranged from 19 to 50 percent of the total waste produced. Waste production figures for the 1978 season were not available.

At Cordova, 1978 seasonal fish catches and processing levels were far below pre-season estimates. Consequently, operations at three of the canneries (St. E., NPP, and Morpac) were at less than half their normal seasonal levels when the

TABLE 12

ESTIMATED SEAFOOD WASTE PRODUCTION
ST. ELIAS OCEAN PRODUCTS *

Type of Waste	Waste Quantity (Tons/year) 1977	1976	1975
Salmon	951	749	425
Tanner Crab	108	710	390
Dungeness Crab	45.5	14.0	48.2
Halibut	-	-	-
Herring	-	-	-

TABLE 13

ESTIMATED SEAFOOD WASTE PRODUCTION
NORTH PACIFIC PROCESSORS, INC. *

Type of Waste	Waste Quantity (Tons/year) 1977	1976	1975
Salmon	1,260	1,040	890
Tanner Crab	337	240	797
Dungeness Crab	0.4	-	2.1
Halibut	1.0	1.0	-
Herring	-	-	-

---

*Ref. 23

TABLE 14

ESTIMATED SEAFOOD WASTE PRODUCTION NEW ENGLAND FISH COMPANY*

	Waste Quantity (Tons/year)		
Type of Waste	1977	1976	1975
Salmon	1,150	843	--
Tanner Crab	--	--	--
Dungeness Crab	--	--	--
Halibut	--	--	--
Herring	18.3	--	--

*Ref. 23

field sampling was conducted. The majority of the processing at this time was of Dungeness crab. One cannery, NEFCO, never opened because of the poor season. However, some field samples were collected from two stations at the NEFCO Cannery in an effort to assess conditions at an outfall area in which no waste discharges had occurred for nearly a year.

Aesthetic Conditions

Some surface discolorations and floating debris were observed near the St. E. dock and in the vicinity of the NPP outfall. At the St. E. dock, the major aesthetic problem was from floating debris associated with the dumping of whole crab shells and some crab appendages off the center of the dock. According to cannery officials, this practice occurred because the cannery grinder system was inoperative and alternative methods for disposal of processing wastes were not available. The majority of this waste sank to the bottom shortly after dumping and comparatively small amounts remained on the surface.

At NPP, a surface plume was observed in the vicinity of the cannery outfall following each discharge. The effluent caused a whitish-yellow discoloration of the surface water. Considerable feeding by sea gulls on larger particulate matter in the surface plume occurred. Because of the intermittent nature of the discharges, the plume was not continuous. However, patches of floating debris from previous discharges were recorded over 45 m from the discharge point.

No aesthetic problems were observed at Morpac, NEFCO, or the non-outfall stations.

Bottom Accumulations

Underwater photography of the St. E. discharge line and outfall area revealed that the line was broken off approximately 2 m from the cannery dock. Prior to this observation, the plant manager had estimated the outfall to be located in the inlet, approximately 45 to 60 m off the cannery dock. According to the manager, the line had once extended at least 75 m from the northwest corner of the dock toward Station C; however, at least half of the line had broken off when a fully loaded tender ~~boat~~ set on the line during a low-tide in late spring. No evidence of the broken section was recorded in the films. Sediment deposition in the bottom of the 2 m portion indicated that this discharge line had not been recently used. Twenty to thirty large starfish were attached to the line, and several were also attached to nearby pilings.

Video films taken of the inlet bottom, to a distance of 15 m directly off the end of the broken outfall, showed a few scattered fish heads in various states of decomposition, and empty crab shells. Numerous flatfish (halibut and starry flounder) were also observed feeding off the bottom in this immediate area. Judging by the sediment buildup in the pipe, it appeared that no discharges had recently occurred, and the area in front of the pipe was relatively clean.

Bottom conditions below the center of the dock-face and to a distance of 15 m off the dock were also filmed. Directly below the dock approximately 80 percent of the bottom was covered with whole empty crab shells and some crab appendages. In some areas the shells were piled on top of one another to a height of 25-30 cm. At a distance of 3 m, the piles thinned out. At 5 m the coverage was estimated at 50 percent and no piles or layering of shells were observed. Flatfish were abundant and actively swimming and feeding in the area of the larger piles. A large ray was observed on top of one of the piles and a few live adult Dungeness crabs were also noted in this area. At 10 and 15 m from the dock the bottom was comparatively clean with approximately 5 percent coverage by empty crab shells. The percent coverage of crab shells under the dock was very low, 1 percent or less. From the film record it appeared that the greatest accumulation of crab wastes occurred directly below the center of the dock, and extended in a semi-circle out from the dock for a distance of 5 m. The center of this impacted area was approximately 16 m from the St. E. outfall.

At NPP, the discharge pipe consists of an approximate 30 m long 10 cm steel pipe which runs off the northwest corner of the cannery and into the inlet. The line was in use and several discharges occurred during the filming period.

The pipe is supported roughly 25 cm off the bottom, and discharges from the pipe have cut a trough 3 m wide and over 6 m long in front of the outfall. The depth of the trough could not be determined because of debris in the trough. The trough contained considerable fish and crab processing wastes of various sizes. Numerous fish tails and heads were observed although crab exoskeletal wastes were estimated at 90 percent of the waste material. The crab wastes averaged 5 cm in size. At one point, the diver pushed his arm into the waste pile up to his shoulder and did not touch a hard bottom. Considerably greater fish activity was observed around this waste pile than at Station E. At any one time during the filming, the diver reported minimally 40-50 flatfish measuring 0.3 m or larger in length. Discharges which occurred during the filming did not contain particles the size of those represented in the trough. The discharges were murky and appeared to consist of only fine particulate matter.

At Morpac, the discharge pipe terminates at the end of the cannery dock, where the pipe makes a right angle turn down into the water and ends approximately 1.5 m above the bottom (Station I). Discharges from the pipe are, therefore, vertical ~~directed down~~ rather than horizontal~~ly~~. This discharge pattern has created a depression in the bottom directly below the outfall which is approximately 0.6 m deep. Surface sediment in this depression, and for a circular area of 12-16 m in diameter around the depression, consisted of a layer of primarily silt and finely ground fish and crab parts. The layer appeared to be 15 to 30 cm deep, and in some instances the diver could not discern the type of waste because the particle size was so small. The waste material appeared to be more finely ground than at the NPP outfall and it did not appear as fresh as the waste debris at NPP or at the crab pile near station St. E. According to cannery officials, processing had occurred during this season, but at reduced levels. It could not be determined whether the observed waste layer represented accumulations from this year, previous years, or both. Very few flatfish were seen in this outfall area. Some starfish and sea anemones were attached to a piece of pipe rising out of the bottom.

Two disposal areas are used at the NEFCO Cannery. Processing wastes are discharged off the end of a gurry trough (Station GT), or through a 120 m long flexible plastic discharge pipe. This discharge pipe is laid in the inlet off the cannery (Station N-0) when the cannery is in operation.

Films of the bottom at Station GT showed no evidence of processing waste accumulations from previous years. The sediment appeared to be primarily sand and silt with numerous burrows in the sediment. No organisms were identified with these burrows during the filming. Very few flatfish were observed in this area.

At Station N-0, the bottom was also clean with a few scattered empty clam shells. No crab or fish debris from previous years was apparent. Within a few meters of Station N-0, an area covered by a 15 cm layer of wood chips, clam shells, and silt was noted, but the dimensions of the layer were not recorded. The origin of the wood chips and the reason for their appearance at this station is not presently known. Several large brown algae (4-6 m in length), flatfish, and active crabs were recorded in this area.

Bottom conditions at Station M and at a station mid-way between Stations K and L were very similar. No crab shells or fish parts were observed, although the incidence of empty mollusc shells and shell fragments was high; in some areas viewed, bottom coverage was estimated at over 50 percent at both points. A few flatfish measuring 30 cm or less in length were viewed, as well as other unidentified small fish, and several epibenthic invertebrates. The invertebrates included hermit crabs, decorator crabs, and sea anemones.

Films of Stations N, O, and P showed these stations to have similar bottom conditions. The bottom appeared to be predominantly sand with irregular troughs and ridges caused by bottom currents. Detrital material had collected along the ridges and was noticeably darker in color than the surrounding sand. The bottom was virtually barren except for a few whole mollusc shells which measured less than 1 cm in width. Very few flatfish were observed, and these were small (<15 cm in length).

Hydrological Conditions

Tidal height data for Cordova is listed in Table 15. Maximum tidal fluctuation at Cordova measured 3.7 m, or less than half of the tidal range values observed at Kenai.

Tidal current data for the mid-channel and control stations is listed in Table 16. Distinct ridge and swale patterns on the sediment surface and the generally barren sediment surface, as revealed by the underwater films, gave further evidence of strong tidal current action at these stations.

TABLE 15. TIDAL DATA FOR CORDOVA, ALASKA
JULY 29-AUGUST 1, 1978*

Date	LW	HW	LW	HW	Maximum Diurnal Range
	meters (feet)				
July 29	0.5 (1.8)	2.6 (8.4)	1.3 (4.3)	3.4 (11.1)	2.9 (9.3)
July 30	0.4 (1.3)	2.7 (8.9)	1.3 (4.2)	3.5 (11.4)	3.1 (10.1)
July 31	0.2 (0.7)	2.9 (9.4)	1.2 (3.9)	3.6 (11.7)	3.4 (11.0)
August 1	0.0 (0.0)	3.1 (10.0)	1.0 (3.4)	3.7 (12.1)	3.7 (12.1)

*Ref. 13

Legend: LW = Low Water
HW = High Water

TABLE 16. TIDAL CURRENT DATA FOR MID-CHANNEL AND CONTROL STATIONS IN ORCA INLET, CORDOVA, ALASKA, JULY 26-AUGUST 1, 1978.

	Maximum Tidal Current			
	Ebb	Flood	Ebb	Flood
Date	In km/hr (knots)			
July 29	2.8 (1.5)	1.3 (0.7)	1.9 (1.0)	1.5 (0.8)
July 30	3.0 (1.6)	1.5 (0.8)	2.0 (1.1)	1.5 (0.8)
July 31	3.3 (1.8)	1.9 (1.0)	2.4 (1.3)	1.7 (0.9)
August 1	3.7 (2.0)	2.0 (1.1)	2.8 (1.5)	1.9 (1.0)

*Ref. 14

Although current measurements were not made at the cannery outfall or dumping areas, the extent of waste accumultion at St. E. and at NPP suggested that currents and tidal flushing were insufficient to adequately disperse the wastes at these two sites. At the Morpac outfall (Station I), the wastes appeared to be more evenly distributed along the bottom, but their persistance indicated insufficient flushing action to fully clean this outfall area of debris. The absence of waste debris at both NEFCO outfalls suggested that the NEFCO discharge areas received good flushing action and that problems with persistent waste accumultions did not occurr.

Water Quality

Water quality data for Cordova stations are presented in Table 17.

Dissolved oxygen concentrations were generally 10 mg/ℓ or higher, and at no stations were there indications of depressed oxygen concentrations. Temperature values indicated a pattern of surface heating and stratification by late afternoon, followed by breakdown of this stratification during the night, and a return to near isothermal conditions by morning. Shallower water stations B, E, and F developed higher bottom water temperatures resulting from surface to bottom mixing over these shallower depth ranges. At one deeper station, the NPP outfall, bottom temperature was higher (13.5° C) than would have been expected from water column mixing alone. The higher value reported for bottom water at this station was probably the result of cannery discharge of warmer water effluent.

TABLE 17. WATER QUALITY AND DEPTH FOR CORDOVA SAMPLING STATIONS.

Parameter		Stations																			
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	NPP	St. Elias	NEFCO GT	NEFCO N-O
Date (1978)		7/30	7/30	7/29	7/29	7/30	7/30	7/30	7/30	7/30	7/30	7/29	7/29	7/29	8/1	8/1	8/1	7/31	7/31	8/2	8/2
Time		0950	1550	1835	1755	1610	1630	1035	1125	1200	1300	1720	1635	1600	950	1100	1200	1345	1500	1150	1220
Depth (m)		6.5	1.1	12.5	8.8	0.8	1.0	7.5	6.8	7.5	10.5	8.5	8.0	18.0	9	8	8	3.5	3	-	-
Dissolved Oxygen (mg/ℓ)	S	10.7	10.3	10.8	10.9	10.8	10.8	10.8	10.6	10.9	10.7	10.9	11.1	10.9	10.3	10.2	11.1	10.4	10.7	10.0	10.1
	M	10.7	-	10.7	10.9	-	-	10.6	10.7	10.6	10.0	10.7	11.4	11.1	9.9	10.0	-	10.5	-	-	-
	B	10.2	11.1	10.1	10.2	10.7	10.9	10.0	10.1	10.0	9.9	10.5	10.6	10.0	10.3	10.0	-	10.5	10.3	-	-
Temperature (°C)	S	11.9	13.8	13.0	13.5	13.4	13.3	12.0	12.1	12.1	11.8	13.4	13.5	13.1	11.7	12.5	12.8	13.8	13.6	12.9	12.3
	M	11.5	-	12.4	12.2	-	-	11.6	11.6	11.4	11.1	12.4	12.0	11.7	11.4	11.5	-	-	-	-	-
	B	11.5	13.6	11.7	11.9	13.3	13.3	11.4	11.6	11.4	11.1	11.6	11.9	11.8	11.5	11.7	-	13.5	13.6	-	-
Salinity (‰)	S	25.0	26.0	28.0	29.0	28.0	27.0	26.0	28.0	27.0	26.0	30.0	28.0	28.0	28.0	27.0	28.0	28.0	26.0	27.0	26.0
	M	25.0	-	30.0	30.0	-	-	28.0	28.0	30.0	30.0	30.0	28.0	28.0	28.0	28.0	-	25.0	-	-	-
	B	27.0	28.0	28.0	29.0	27.0	28.0	28.0	28.0	29.0	30.0	30.0	28.0	28.0	28.0	28.0	-	24.0	27.0	-	-
pH	S	8.1	8.1	8.2	8.2	8.1	8.2	8.1	8.1	7.9	7.7	8.2	8.1	7.9	8.2	8.2	8.2	7.9	8.1	8.2	8.0
	M	7.8	-	8.1	8.2	-	-	8.2	7.8	8.2	8.2	8.1	8.1	7.7	8.2	8.2	-	8.1	-	-	-
	B	7.7	8.1	8.2	8.2	8.1	8.2	8.2	7.7	8.2	8.1	8.1	8.0	7.8	8.2	8.1	-	8.1	8.2	-	-
Seechi Depth (m)		1.89	-	2.00	2.09	-*	-*	2.15	1.70	1.6	2.0	2.24	2.25	2.43	2.0	1.95	-	1.62	-	-	-
Ammonia (mg/ℓ)	S	ND†	0.06	ND	< 0.02	0.12	0.11	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND	0.11	0.06	-	-
	M	ND	-	0.02	ND	-	-	ND	ND	0.02	ND	< 0.02	0.02	ND	ND	ND	-	0.08	-	-	-
	B	0.03	0.02	ND	< 0.02	0.03	0.09	< 0.02	0.05	0.04	0.04	ND	ND	ND	ND	ND	-	0.12	0.46	-	-
Organic Nitrogen (mg/ℓ)	S	0.04	0.06	0.03	0.03	0.15	0.13	0.04	0.05	0.05	0.04	0.02	0.03	0.03	0.02	0.04	0.02	0.13	0.17	-	-
	M	0.04	-	0.02	0.02	-	-	0.03	0.06	0.04	0.03	0.02	0.05	0.02	0.02	0.03	-	0.14	-	-	-
	B	0.06	0.09	0.03	0.04	0.06	0.12	0.03	0.08	0.05	0.04	0.02	0.03	0.03	0.04	0.04	-	0.23	0.53	-	-
Orthophosphate (mg/ℓ)	S	0.02	0.05	0.02	0.02	0.03	0.02	0.02	0.02	0.02	ND	0.02	0.02	0.02	0.03	ND	< 0.02	0.04	0.04	-	-
	M	ND	-	0.02	0.02	-	-	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	-	0.04	-	-	-
	B	0.03	0.03	0.02	0.02	0.04	0.03	0.03	0.04	0.03	0.03	0.02	0.02	0.03	ND	0.02	-	0.05	0.08	-	-
Total Phosphorus (mg/ℓ)	S	0.03	0.05	0.03	0.03	0.05	0.05	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	ND	0.04	0.09	-	-
	M	0.02	-	0.04	0.03	-	-	0.03	0.03	0.03	0.02	0.04	0.05	0.03	0.03	0.03	-	0.05	-	-	-
	B	0.03	0.05	0.03	0.03	0.06	0.05	0.04	0.05	0.04	0.03	0.02	0.03	0.04	0.03	0.04	-	0.05	0.10	-	-
Sulfide (mg/ℓ)	S	ND*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
	M	ND	-	ND	ND	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	ND	-	-	-
	B	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND	-	0.011	0.014	-	-

*Bottom visible from surface.

†ND = Not detectable.

With the exception of Stations NPP and A, salinity values ranged between 27‰ to 30‰. The lowest values observed (24‰) were from bottom water samples at NPP and in surface and midwater samples at Station A. The lower value at Station NPP appeared to have been the result of fresh water dilution from cannery wastewater discharges at this depth. Low surface and mid-water values at Station A probably resulted from terrestrial freshwater drainage into the mudflat area near Station A.

Little variation in pH was observed between stations. Ammonia nitrogen values were highest in the vicinity of Stations NPP and St. E. Waste disposal activities and decomposing crab wastes on the bottom near the St. E. outfall station probably contributed to the high ammonia value recorded at Station St. E. Elevated ammonia values were also observed at Stations B, E, and F. Poor flushing action in these shallow embayments may have accounted for these higher readings.

Orthophosphate values were also slightly higher at Stations NPP and St. E., while total phosphorus values did not differ appreciably between stations with the exception of Station St. E. Total phosphorus values at this outfall station were two to three times greater than other station values. Sulfide and organic nitrogen values were also noticeably higher at stations NPP and St. E.

Sediment Particle Size

Particle size distributions for Cordova marine sediments are shown in Table 18. Stations B, E, and F were not sampled

TABLE 18. SIZE DISTRIBUTION (PERCENT WEIGHT) OF CORDOVA SEDIMENT SAMPLES

	Station																
Size Class	A	C	D	G	H	I	J	K	L	M	N	O	P	NPP	St. Elias	NEFCO GT	NEFCO N-O
Gravel*	0	0	4	0	0	0	5	0	0	0	0	0	0	0	1	0	4
Sand†	55	57	60	60	54	13	66	82	60	90	95	94	95	41	17	70	68
Silt#	35	33	11	31	37	41	6	7	6	1	3	2	1	8	41	24	17
Clay**	10	10	5	9	9	14	9	6	4	4	2	4	4	14	16	6	11
Other			20 (C)			32 (F&C)	14 (C)	5 (M)	30 (M)	5 (M)				37 (F&C)	25 (C)		

(C) = Crustacean Exoskeletal Fragments

(M) = Mollusc Shell Fragments

(F) = Fish Skeletal Fragments

Legend

*Gravel - >2 mm
†Sand - 50 microns to 2 mm
#Silt - 2-50 microns
**Clay - <2 microns

because their shallow depth or submerged obstacles made these stations inaccessible to the research vessel. Sediment samples typically had a sand content of 50 percent or more. Few stations had gravel, although several stations, particularly those at outfalls, had comparatively high percentages of fish skeletal, crab shell, or crab exoskeletal fragments which were retained on the No. 10 sieve (72 mm). Crab exoskeletal and fish skeletal fragments were found at all operating outfalls, and crab exoskeletal fragments were also found at Station D. Stations M, K, and L had empty mollusc shells and shell fragments. The highest silt concentrations were recorded at two outfall stations, I, and St. E. Stations A, C, D, G, H, NPP, NEFCO GT, and NEFCO N-O, had similar sediment characteristics, with the exception of varying amounts of shell or skeletal fragments at some of these stations. Stations J, K, L, M, N, O, and P, were primarily sand.

Sediment Chemistry

The results of sediment chemistry analyzes for Cordova are shown in Table 19. In comparison to Kenai River sediments, TVS content of Cordova sediments was several fold higher. The highest values were recorded at Stations H (23.0 percent) and at NPP (24.5 percent). TOC was highest at NPP (0.264 percent), and L (0.289 percent).

Total sulfide was considerably higher at outfall stations I, and St. E. The total sulfide value at Sation NPP was surprisingly low in view of the high total sulfide values

TABLE 19 . SEDIMENT CHEMISTRY DATA FOR CORDOVA SAMPLING STATIONS

	A	C	D	G	H	I	J	K
Volatile Solids (%)	9.01	10.0	16.8	5.90	23	9.20	15.80	13.4
Total Organic Carbon (%)	0.065	0.014	0.137	0.149	0.044	0.062	0.129	0.022
Total Sulfide (mg/kg) (dry)	72.8	54.8	219	275	94.7	399	54.4	61.3
Total Kjeldahl Nitrogen (mg/kg) (dry)	731	462	311	302	346	2620	612	1017

	L	M	N	O	P	NPP	St. Elias	NEFCO GT	NEFCO N-C
Volatile Solids (%)	16.5	7.40	7.18	4.70	7.0	24.5	11.1	12.4	9.09
Total Organic Carbon (%)	0.289	.007	0.004	0.10	0.003	0.264	0.160	0.053	0.075
Total Sulfide (mg/kg) (dry)	121	29.6	26.3	13.3	15.6	72.7	380	138	125
Total Kjeldahl Nitrogen (mg/kg) (dry)	1904	302	628	480	253	4510	1353	518	304

observed at the other outfall stations. TKN concentrations were high at outfall Stations I (2,620 mg/kg), NPP (4,510 mg/kg), and St. E (1,353 mg/kg). TKN concentrations at the NEFCO outfall stations were considerably lower than the operating outfalls (518 mg/kg, NEFCO GT; 304 mg/kg, NEFCO N-O). Mid-channel Stations K and L, however, also showed high TKN concentrations possibly from mollusc decomposition in the sediment at these stations.

Macrobenthos

Listings of the macrobenthos organisms collected on the 1 mm and 0.5 mm screens, and on the combined screens are given in Tables 20, 21, and 22, respectively. The number appearing to the left of each species represents the species code used for numerical analysis of the data. Shallow water stations B, E, and F, were not accessible by the research vessel and thus were not sampled. At Station NPP, the depth and extent of fish and crab wastes prevented collection of satisfactory benthic samples.

A total of 78 species in the 1 mm screenings, and 41 in the 0.5 mm screenings were recovered. An additional 17 species were identified from the 0.5 mm material which were not identified in the 1 mm material. Thus, a total of 95 species were recovered in all the Cordova sediment samples.

Density, species richness, and species diversity values for the 1 mm, 0.5 mm, and combined data are shown for each Cordova station in Tables 23, 24, and 25 respectively. The 1 mm data in

TABLE 20. STATION LIST OF MACROBENTHOS OF CORDOVA SEDIMENTS (1 mm SCREENINGS)

Species Code		-STATION- A	C	D	G	H	I	J	K
1.	*Ampharete arctica*	1		1	28	2	1	3	2
3.	*Aoroides* sp. 1			1				3	
4.	*Armandia brevis*	29	4	76	5	28	1	49	5
5.	*Anaitides mucosa*	3	1			4		1	1
6.	*Axinopsida serricata*	307	34	30	52	59	10	30	4
7.	*Bathymedon* sp. 1								
8.	*Boccardia* sp. 1	1							
9.	*Capitella capitata*	48	2	55	12	11	2		
10.	*Cistenides brevicoma*	13	1	28		15	4	9	2
11.	*Cirratulus cirratus*	2		4				6	1
12.	*Clinocardium nuttallii*	18	1	2	3	21		1	1
13.	*Corophium* sp. 1							2	1
14.	*Cryptobranchia alka*			1				6	
15.	*Cylichna occulata*	16			8	3			
16.	*Diastylis alaskensis*	31		1	3	33		20	2
17.	*Eteone longa*	4		27	4	5	3	1	2
18.	*Euhaustorius washingtonianus*								
19.	*Gastropteron pacificum*	1		1	4				
20.	*Glycinde picta*	18	1	3	8	8		6	1
21.	*Haploscoloplos elongata*	68	1	12	20	29		3	6
22.	*Harmothoe imbricata*			13		1		18	3
23.	*Harpiniopsis* sp. 1								
24.	*Hemipodus borealis*			1					
25.	Hesionidae			1				2	
26.	*Hiatella arctica*		1			1		2	
27.	*Lacuna* sp. 1								
28.	*Lamprops* sp. 1	1				1		1	1
29.	*Lumbrineris luti*	29		3	2	11		5	
30.	*Lumbrineris* sp. 1								
31.	*Macoma inquinata*	26	5	80	11	19	15	12	3
32.	*Macoma moesta alaskana*	116	5	14	51	42	1	5	2
33.	*Magelona* sp. 1	2							
34.	*Melita dentata*			4				5	2
35.	*Mitrella gouldi*	6				2		1	
36.	*Monoculodes* sp. 1							3	3
37.	*Musculus niger*	1		1			1		
41.	*Mya* sp. 1							2	1
38.	*Mysella tumida*	59	3	100	7	78	1	6	
39.	*Mysella* sp. 1			33					
40.	Mysta *barbata*	4				6			

TABLE 20 (CONTINUED)

		L	M	N	O	P	NEFCO GT	NEFCO N-O	St.E.
1.	*Ampharete arctica*	7						3	
3.	*Aoroides* sp. 1								
4.	*Armandia brevis*	22					6	53	
5.	*Anaitides mucosa*	3						7	
6.	*Axinopsida serricata*	12					20	256	1
7.	*Bathymedon* sp. 1		1	11	7				
8.	*Boccardia* sp. 1	1					9	152	
9.	*Capitella capitata*	4						12	252
10.	*Cistenides brevicoma*	41					2	38	
11.	*Cirratulus cirratus*	4							
12.	*Clinocardium nuttallii*	1						1	
13.	*Corophium* sp. 1	2						3	
14.	*Cryptobranchia alka*								
15.	*Cylichna occulata*	1							
16.	*Diastylis alaskensis*	2							
17.	*Eteone longa*	2				1		45	8
18.	*Euhaustorius washingtonianus*		5	24	19	25			
19.	*Gastropteron pacificum*	1							
20.	*Glycinde picta*	2	1					9	
21.	*Haploscoloplos elongata*	20	8	15	5	15	18	42	
22.	*Harmothoe imbricata*	8						11	
23.	*Harpiniopsis* sp. 1		20						
24.	*Hemipodus borealis*	2						3	
25.	Hesionidae	1							
26.	*Hiatella arctica*							3	
27.	*Lacuna* sp. 1							11	
28.	*Lamprops* sp. 1	1	2	2		1			
29.	*Lumbrineris luti*	10					2	14	
30.	*Lumbrineris* sp. 1							12	
31.	*Macoma inquinata*	6			1	1	5	78	2
32.	*Macoma moesta alaskana*	15	5	3	2	1	1	5	
33.	*Magelona* sp. 1	3	20	7	6	9			
34.	*Melita dentata*	9						1	
35.	*Mitrella gouldi*								
36.	*Monoculodes* sp. 1	2	1	1	1	1			
37.	*Musculus niger*	1							
41.	*Mya* sp. 1	1					1	1	
38.	*Mysella tumida*	5				18	1	12	
39.	*Mysella* sp. 1								
40.	*Mysta barbata*	1							

TABLE 20(CONTINUED)

		A	C	D	G	H	I	J	K
42.	*Nassarius mendicus*	7		6	2	1		8	1
2.	*Neosabellides* sp. 1	161			33	325	44		
43.	*Nephtys cornuta*	13		2	3	11		2	2
44.	*Nephtys caeca*			1	1				
45.	*Nephtys ciliata*							1	1
46.	*Nephtys* sp. 1					2	1		2
47.	*Nereis* sp. 1			1				1	
48.	*Odostomia* sp. 1			11	2	1		6	1
49.	*Oenopota* sp.					1		3	1
50.	*Olivella biplicata*				1			9	
51.	*Olivella baetica*	1		1	1	1	1		13
52.	Ophiuroidea	2		1	6	21		1	1
53.	*Orchomene* sp.1			3		1			
54.	Oweniidae	1				3			4
55.	*Pagarus ochotensis*			1				28	
56.	*Paraphoxus* sp. 1			1				3	
57.	*Phloe minuta*	37		2	10	14		5	
58.	Phoxocephalidae								
59.	*Pleusymtes* sp. 1	1				5		1	1
60.	*Polycirrus* sp. 1								
61.	*Polydora socialis*			1				3	
62.	*Pontocrates arenarius*								
63.	*Prionospio malmgreni*	269		70	64	51	6	150	22
64.	*Protomedeia* sp. 1				1	2		2	4
65.	*Protothaca staminea*	1	2	11	2	4		18	
66.	*Psephidia lordi*	6	8	5	10	8	1	3	
67.	*Pycnogonida* sp. 1			1				2	1
68.	*Saxidomus giganteus*	1	2	14	2			7	2
69.	*Scolelepsis cirratulus*								
70.	*Scoloplos armiger*								
71.	*Solariella obscura*								
72.	*Spio filicornis*	5		6	4	4	1	1	2
73.	*Spiophanes bombyx*			1					
74.	*Streptosyllus* sp. 1								
75.	*Paraonis gracilis*								
76.	*Turbonilla* sp. 1	3				18		2	
77.	*Westwoodilla* sp. 1								
78.	*Yoldia amygdalea*	1		1		4		1	
	Total Species Number	40	15	45	30	39	15	49	33

TABLE 20 (CONTINUED)

		L	M	N	O	P	NEFCO GT	NEFCO N-O	St.E.
42.	*Nassarius mendicus*	23						13	
2.	*Neosabellides* sp. 1					1	3	32	
43.	*Nephtys cornuta*	2			1	2	4	29	
44.	*Nephtys caeca*		2	1	1				
45.	*Nephtys ciliata*	2							
46.	*Nephtys* sp. 1	2				2	3	4	
47.	*Nereis* sp. 1	1						4	
48.	*Odostomia* sp. 1					1			
49.	*Oenopota* sp.								
50.	*Olivella biplicata*								
51.	*Olivella baetica*	35	10			1	1		
52.	Ophiuroidea		1					3	
53.	*Orchomene* sp.1	5							
54.	Oweniidae	15						1	
55.	*Pagarus ochotensis*								
56.	*Paraphoxus* sp. 1	3	8	15	6	8			
57.	*Phloe minuta*	2					1	21	
58.	Phoxocephalidae		2	28	12	29			
59.	*Pleusymtes* sp. 1	1							
60.	*Polycirrus* sp. 1	6							
61.	*Polydora socialis*						2		
62.	*Pontocrates arenarius*		2	2	1	2			
63.	*Prionospio malmgreni*	56					5	17	
64.	*Protomedeia* sp. 1	1						2	
65.	*Protothaca staminea*							4	
66.	*Psephidia lordi*	1				42		4	
67.	*Pycnogonida* sp. 1								
68.	*Saxidomus giganteus*	1				1		9	
69.	*Scolelepsis cirratulus*				3	1			
70.	*Scoloplos armiger*				8				
71.	*Solariella obscura*		2	2	3				
72.	*Spio filicornis*	21	10	3	4	6		2	
73.	*Spiophanes bombyx*	1	2	2	1	1			
74.	*Streptosyllus* sp. 1				4				
75.	*Paraonis gracilis*		8	1	4	14			
76.	*Turbonilla* sp. 1							3	
77.	*Westwoodilla* sp. 1		19	10	10	40			
78.	*Yoldia amygdalea*	1							
	Total Species Number	48	19	15	19	22	16	35	4

TABLE 21. STATION LIST OF MACROBENTHOS OF CORDOVA SEDIMENTS (0.5 mm SCREENINGS)

Species Code		A	C	D	G	H	I	J	K
1.	Amphipoda					62		7	20
2.	*Ampharete arctica*	11		92	3				1
3.	*Armandia brevis*	4	10	92	40	66		43	5
4.	*Axinopsida serricata*	15		7	4	34	28	16	
5.	*Aricidea* sp. 1					15		4	5
6.	Aceola	36			5	4			
7.	*Bathymedon* sp. 1					15		35	
8.	*Capitella capitata*	80	3	143	65	48			
9.	*Cistenides brevicoma*				1	4		34	4
10.	*Clinocardium* sp. 1	232			24	96			
11.	Cirratulidae	4						13	1
12.	*Diastylis* sp. 1				2	29		13	
13.	*Eteone longa*	7	4	5	10	11			1
14.	*Euhaustorius washingtonianus*								1
15.	*Euhaustorius* sp. 1								
16.	Harpacticoida	113			18	34		118	
17.	*Haploscoloplos elongata*	22		28	45	119		53	40
18.	*Lamprops* sp. 1				1	8		14	1
19.	*Lumbrineris luti*	4			21	82			1
20.	*Lumbrineris* sp. 1	51		12		84		9	2
21.	*Magelona* sp. 1	22			6			7	5
22.	*Munna* sp. 1	33			10	15		16	
23.	Mytilidae	11			5	4	57	49	
24.	*Macoma* sp. 1							69	
25.	*Macoma moesta alaskana*	40		12	26	81		24	1
26.	*Monoculodes* sp. 1	4						47	30
27.	*Mysella tumida*	4		108	33	70		156	4
28.	*Nephtys cornuta*	25			7	48		4	
29.	*Neosabellides* sp. 1	40			145	405	69	7	
30.	Nematoda	4048	682	963	658	2481	1365	653	209
31.	Ostracoda	22			5			47	
32.	Oligochaeta					26			
33.	Ophiuroidea				11				1
34.	*Phloe minuta*	145		7	33	225		81	3
35.	*Prionospio malmgreni*	258		154	163	325		267	73
36.	*Rhychospio* sp. 1	18		19	9	91		28	1

TABLE 21 (CONTINUED)

Species Code		L	M	N	O	P	NEFCO GT	NEFCO N-O	St.E.
1.	Amphipoda	16	17	2					
2.	*Ampharete arctica*	3							
3.	*Armandia brevis*	22			1		44	86	
4.	*Axinopsida serricata*	41		1				159	
5.	*Aricidea* sp. 1		19		1				
6.	Aceola					3			
7.	*Bathymedon* sp. 1	14		7		8		40	
8.	*Capitella capitata*	3						42	
9.	*Cistenides brevicoma*	3							
10.	*Clinocardium* sp. 1						64	4	
11.	Cirratulidae	8			1		64	43	
12.	*Diastylis* sp. 1								
13.	*Eteone longa*	7						38	38
14.	*Euhaustorius washingtonianus*			27	22	14			30
15.	*Euhaustorius* sp. 1		7						
16.	Harpacticoida	3	9	1	6	92		20	
17.	*Haploscoloplos elongata*	64	2	2	1	5	44	58	
18.	*Lamprops* sp. 1		2	3	3	8			
19.	*Lumbrineris luti*		1					40	
20.	*Lumbrineris* sp. 1	4		1				43	
21.	*Magelona* sp. 1	6	11	13	3	5			
22.	*Munna* sp. 1								
23.	Mytilidae					1		25	
24.	*Macoma* sp. 1								
25.	*Macoma moesta alaskana*	15	1		2	3		7	
26.	*Monoculodes* sp. 1			1				25	
27.	*Mysella tumida*	69	2	4		1		106	
28.	*Nephtys cornuta*	6	1			3		20	
29.	*Neosabellides* sp. 1	3						272	
30.	Nematoda	385	24	6	5	30	1766	1512	4836
31.	Ostracoda	28	2	2	3			67	
32.	Oligochaeta	134							
33.	Ophiuroidea								
34.	*Phloe minuta*		2					169	
35.	*Prionospio malmgreni*	108	3		1	10	64	60	
35.	*Rhychospio* sp. 1			1				31	

TABLE 21 (CONTINUED)

		A	C	D	G	H	I	J	K
37.	*Spio filicornis*				1				6
38.	*Spiophanes bombyx*				5				
39.	*Sphaerosyllis brandhorsti*	4				15		16	
40.	Syllidae					15			
41.	*Paraonis gracilis*	44		13	10	11			6
	Total Species Number	27	4	13	29	30	4	27	23

TABLE 21 (CONTINUED)

		L	M	N	O	P	NEFCO GT	NEFCO N-O	St.E.
37.	*Spio filicornis*				2	1			
38.	*Spiophanes bombyx*		2	1	1	7			
39.	*Sphaerosyllis brandhorsti*		1					18	
40.	Syllidae	4	37	19	33	32		20	
41.	*Paraonis gracilis*			17	16	56			
	Total Species Number	22	18	17	16	18	5	24	3

TABLE 22. STATION LIST OF MACROBENTHOS OF CORDOVA SEDIMENTS (1 mm and 0.5 mm SCREENINGS)

Species Code		A	C	D	G	H	I	J	K
		-STATION-							
1.	Aceola	36			5	4			
2.	*Ampharete arctica*	12		1	31	2	1	3	3
3.	Amphipoda					62			1
4.	*Anaitides mucosa*	3	1			4		1	1
5.	*Aoroides* sp. 1			1				3	
6.	*Aricidea* sp. 1					15		4	5
7.	*Armandia brevis*	33	14	168	45	44	1	92	10
8.	*Axinopsida serricata*	322	34	37	56	93	38	46	4
9.	*Bathymedon* sp. 1					15		35	
10.	*Boccardia* sp. 1	1							
11.	*Capitella capitata*	128	5	198	77	59	2		
12.	*Cirratulus cirratus*	2		4				6	1
13.	Cirratulidae	4					13	1	
14.	*Cistenides brevicoma*	13	1	28	1	19	4	43	6
15.	*Clinocardium nuttallii*	18	1	2	3	21		1	1
16.	*Clinocardium* sp. 1	232			34	96			
17.	*Corophium* sp. 1							2	1
18.	*Cryptobranchia alka*			1				6	
19.	*Cylichna occulata*	16			8	3			
20.	*Diastylis alaskensis*	31		1	3	33		20	2
21.	*Diastylis* sp. 1				2	29		12	
22.	*Eteone longa*	11	4	32	14	16	3	1	3
23.	*Eohaustorius washingtonianus*								1
24.	*Eohaustorius* sp. 1								
25.	*Gastropteron pacificum*	1		1	4				
26.	*Glycinde picta*	15	1	3	3	8		6	1
27.	*Haploscoloplos elongatus*	90	1	40	65	148		56	41
28.	*Harmothoe imbricata*			13	1			18	3
29.	Harpacticoida	[illegible]			18	34		[illegible]	
30.	*Harpiniopsis* sp. 1								
31.	*Hemipodus borealis*			1					2
32.	Hesionidae			1				2	
33.	*Hiatella arctica*		1			1		2	
34.	*Lacuna* sp. 1								
35.	*Lamprops* sp. 1	1			1	9		10	2
36.	*Lumbrineris luti*	38		3	23	93		5	1
37.	*Lumbrineris* sp. 1	51		12		64		9	2
38.	*Macoma inquinata*	26	5	60	11	19	16	12	3

TABLE 22 (CONTINUED)

Species Code		L	M	N	O	P	NEFCO GT	NEFCO N-O	St.E.
						-STATION-			
1.	Aceola					3			
2.	*Ampharete arctica*	10						3	
3.	Amphipoda	3		2					
4.	*Anaitides mucosa*	3						7	
5.	*Aoroides* sp. 1								
6.	*Aricidea* sp. 1		19		1				
7.	*Armandia brevis*	44			1		50	139	
8.	*Axinopsida serricata*	53		1			20	415	1
9.	*Bathymedon* sp. 1	14	1	18	7	3		40	
10.	*Boccardia* sp. 1	1					9	152	
11.	*Capitella capitata*	7						54	252
12.	*Cirratulus cirratus*	4							
13.	Cirratulidae	8			1		64	43	
14.	*Cistenides brevicoma*	44					2	38	
15.	*Clinocardium nuttallii*	1						1	
16.	*Clinocardium* sp. 1							4	
17.	*Corophium* sp. 1	2						3	
18.	*Cryptobranchia alba*								
19.	*Cylichna occulata*	1							
20.	*Diastylis alaskensis*	2							
21.	*Diastylis* sp. 1								
22.	*Eteone longa*	9				1		83	38
23.	*Eohaustorius washingtonianus*		5	51	41	39			30
24.	*Eohaustorius* sp. 1		7						
25.	*Gastropteron pacificum*	1							
26.	*Glycinde picta*	2	1					9	
27.	*Haploscoloplos elongata*	66	10	17	6	20	62	100	
28.	*Harmothoe imbricata*	8						11	
29.	Harpacticoida	3	9	1	6	92	44	20	
30.	*Harpiniopsis* sp. 1		20						
31.	*Hemipodus borealis*							3	
32.	Hesionidae	1							
33.	*Hiatella arctica*							3	
34.	*Lacuna* sp. 1							11	
35.	[illegible] sp. 1	1	4	5	3	9			
36.	*Lumbrineris luti*	10	1				2	54	
37.	*Lumbrineris* sp. 1	4		1				55	
38.	*Macoma inquinat*	6			1	1	5	78	2

TABLE 22 (CONTINUED)

		A	C	D	G	H	I	J	K
39.	*Macoma moesta alaskana*	156	5	26	77	123	1	29	3
40.	*Macoma* sp. 1							69	
41.	*Magelona* sp. 1	24			6			7	5
42.	*Melita dentata*			4				5	2
43.	*Mitrella gouldi*	6				2		1	
44.	*Monoculodes* sp. 1	4						50	33
45.	*Munna* sp. 1	33			10	15		16	
46.	*Musculus niger*	1		1				1	
47.	*Mya* sp. 1							2	1
48.	*Mysella tumida*	63	3	208	40	143	1	162	4
49.	*Mysella* sp. 1			33					
50.	*Mysta barbata*	4				6			
51.	Mytilidae	11			5	4	57	49	
52.	*Nassarius mendicus*	7		6	2	1		8	1
53.	Nematoda	4048	682	963	658	2481	1365	653	209
54.	*Neosabellides* sp. 1	201			177	730	113	7	
55.	*Nephtys caeca*			1	1				
56.	*Nephtys ciliata*							1	1
57.	*Nephtys cornuta*	38		2	10	59		6	2
58.	*Nephtys* sp. 1					2	1		2
59.	*Nereis* sp. 1			1					1
60.	*Odostomia* sp. 1			11	2	1		6	1
61.	*Oenopota* sp. 1					1		3	1
62.	Oligochaeta					26			
63.	*Olivella baetica*	1		1	1	1	1		13
64.	*Olivella biplicata*				1			9	
65.	Ophiuroidea	2		1	17	21		1	2
66.	*Orchomene* sp. 1			3		1			
67.	Ostracoda	22			5			47	
68.	Oweniidae	1				3			4
69.	*Pagarus ochotensis*			1				28	
70.	*Paraphoxus* sp. 1			1				3	
71.	*Phloe minuta*	182		9	43	239		86	3
72.	Phoxocephalidae								
73.	*Pleusymtes* sp. 1	1				5		1	1
74.	*Polycirrus* sp. 1								
75.	*Polydora socialis*			1				3	
76.	*Pontocrates arenarius*								

TABLE 22 (CONTINUED)

		L	M	N	O	P	NEFCO GT	NEFCO N-O	St.E.
39.	*Macoma moesta alaskana*	30	6	3	4	4	1	12	
40.	*Macoma* sp. 1								
41.	*Magelona* sp. 1	9	31	20	9	14			
42.	*Melita dentata*	9						1	
43.	*Mitrella gouldi*								
44.	*Monoculodes* sp. 1	2	1	2	1	1		25	
45.	*Munna* sp. 1								
46.	*Musculus niger*	1							
47.	*Mya* sp. 1	1					1	1	
48.	*Mysella tumida*	74	2	4		19	1	118	
49.	*Mysella* sp. 1								
50.	*Mysta barbata*	1							
51.	Mytilidae					1		25	
52.	*Nassarius mendicus*	23						13	
53.	Nematoda	385	24	6	5	30	1766	1512	4836
54.	*Neosabellides* sp. 1	3				1	3	304	
55.	*Nephtys caeca*		2	1	1				
56.	*Nephtys ciliata*	2							
57.	*Nephtys cornuta*	8	1		1	5	4	49	
58.	*Nephtys* sp. 1	2				2	3	4	
59.	*Nereis* sp. 1	1						4	
60.	*Odostomia* sp. 1					1			
61.	*Oenopota* sp. 1								
62.	Oligochaeta	134							
63.	*Olivella baetica*	35	10			1	1		
64.	*Olivella biplicata*								
65.	Ophiuroidea		1					3	
66.	*Orchomene* sp. 1	5							
67.	Ostracoda	28	2	2	3			67	
68.	Oweniidae	15						1	
69.	*Pagarus ochotensis*								
70.	*Paraphoxus* sp. 1	3	8	15	6	8			
71.	*Phloe minuta*	2	2				65	190	
72.	Phoxocephalidae		2	28	12	29			
73.	*Pleusymtes* sp. 1	1							
74.	*Polycirrus* sp. 1	6							
75.	*Polydora socialis*						2		
76.	*Pontocrates arenarius*		2	2	1	2			

TABLE 22 (CONTINUED

		A	C	D	G	H	I	J	K
77.	*Prionospio malmgreni*	527		224	227	376	6	417	95
78.	*Protomedeia* sp. 1				1	2		2	4
79.	*Protothaca staminea*	1	2	11	2	4		18	
80.	*Psephidia lordi*	6	8	5	10	8	1	3	
81.	*Pycnogonida* sp. 1			1				2	1
82.	*Rhychospio* sp. 1	18		19	9	81		28	1
83.	*Saxidomus giganteus*	1	2	14	2			7	2
84.	*Scolelepsis cirratulus*								
85.	*Scoloplos armiger*								
86.	*Solariella obscura*			1					
87.	*Spio filicornis*	5		6	5	4	1	1	8
88.	*Spiophanes bombyx*			1	5				
89.	*Sphaerosyllis brandhorsti*	4				15		16	
90.	*Streptosyllus* sp. 1								
91.	Syllidae					15			
92.	*Paraonis gracilis*	44		13	10	11			6
93.	*Turbonilla* sp. 1	3				18		2	
94.	*Westwoodilla* sp. 1								
95.	*Yoldia amygdalea*	1		1		4		1	
	Total Species Number	52	17	49	44	56	17	63	48

TABLE 22 (CONTINUED)

		L	M	N	O	P	NEFCO GT	NEFCO N-O	St.E.
77.	*Prionospio malmgreni*	164	3		1	10	69	77	
78.	*Protomedeia* sp. 1	1						2	
79.	*Protothaca staminea*							4	
80.	*Psephidia lordi*	1				42		4	
81.	*Pycnogonida* sp. 1								
82.	*Rhychospio* sp. 1			1				31	
83.	*Saxidomus giganteus*	1				1		9	
84.	*Scolelepsis cirratulus*				3	1			
85.	*Scoloplos armiger*				8				
86.	*Solariella obscura*		2	2	3				
87.	*Spio filicornis*	21	10	3	6	7		2	
88.	*Spiophanes bombyx*	1	4	3	2	8			
89.	*Sphaerosyllis brandhorsti*		1					18	
90.	*Streptosyllus* sp. 1				4				
91.	Syllidae	4	37	19	33	32		20	
92.	*Paraonis gracilis*		8	18	20	70			
93.	*Turbonilla* sp. 1							3	
94.	*Westwoodilla* sp. 1		19	10	10	40			
95.	*Yoldia amygdalea*	1							
	Total Species Number	58	32	25	29	31	20	49	6

TABLE 23. DENSITY (N), SPECIES RICHNESS (S), AND DIVERSITY (H') VALUES OF CORDOVA BENTHIC SAMPLES (1 mm SCREENINGS).

Station	N	S	H'
A	1,313	39	2.50
C	71	15	1.93
D	633	45	2.81
G	369	30	2.73
H	851	40	2.54
I	92	15	1.79
J	459	48	2.81
K	102	35	3.05
L	369	49	3.14
M	129	20	2.56
N	127	16	2.28
O	99	20	2.64
P	223	24	2.43
NEFCO GT	84	17	2.35
NEFCO N-O	920	38	2.65
St. E.	263	4	0.21

TABLE 24. DENSITY(N), SPECIES RICHNESS(S), AND DIVERSITY (H') VALUES OF CORDOVA BENTHIC SAMPLES (0.5 mm SCREENINGS)

Station	N	S	H'
A	5,297	27	1.15
C	699	4	0.14
D	1,563	13	1.40
G	1,376	29	2.03
H	4,513	30	1.93
I	1,519	4	0.43
J	1,830	27	2.39
K	467	23	1.88
L	946	22	2.07
M	143	18	2.27
N	108	17	2.24
O	101	16	2.05
P	279	18	2.11
NEFCO GT	1,982	5	0.49
NEFCO N-O	2,905	24	2.00
St. E.	4,904	3	0.08

TABLE 25. DENSITY (N), SPECIES RICHNESS(S), AND DIVERSITY (H') VALUES OF COMBINED CORDOVA BENTHIC SAMPLES (1 mm AND 0.5 mm SCREENINGS)

Station	N	S	H'
A	6,610	52	1.78
C	770	17	0.60
C	2,196	49	2.14
G	1,735	44	2.42
H	5,314	56	2.22
I	1,611	17	0.67
J	2,286	63	2.76
K	501	48	2.26
L	1,282	58	2.71
M	254	32	2.92
N	235	25	2.62
O	200	29	2.76
P	497	31	2.71
NEFCO GT	2,174	20	0.90
NEFCO N-O	3,825	49	2.49
St. E.	5,159	6	0.28

Table 23 indicated a diverse benthic community with the exception of the immediate outfall areas at Stations I and St. E. The lowest species richness (15 and 4, respectively) and diversity values (1.79 and 0.21, respectively) were recorded at these two stations.

For the 0.5 mm data (Table 24) diversity values were lower at all stations with particularly low diversities and species richness values at four stations, C, I, NEFCO GT, and St. E. At these four stations, nematode worms accounted for 89 percent or more of the total species density. The dominance by the nematodes at these four stations, in particular, as well as at other stations, was responsible for the lower diversity values.

Addition of the benthic species retained by the 0.5 mm screen to the 1 mm benthic data reduced species diversity at all stations (Table 25). While stations I and St. E. continued to show low diversity values, a marked reduction in diversity also occurred at Stations C and NEFCO GT. These pronounced reductions, and the overall reductions in diversity, were again the result of the addition of nematode worms from the 0.5 mm data into the total species pool. At Stations C, I, and NEFCO GT, 81 to 89 percent of the total species abundance consisted of nematodes, while at Station St. E, nematodes comprised 93 percent. Of the Cordova stations, St. E, still showed the lowest species richness and diversity values. While species richness was considerably higher at Stations C, I, and NEFCO GT, than at Station St. E., the major dominance by nematodes had reduced diversity valves. With the exception of Stations C, I, NEFCO G-T and St. E., the diversity data indicated a generally diverse benthic community.

Analysis of the combined data again demonstrated the importance of the 0.5 mm material in providing a complete description of the benthic community.

Numerical classification of the combined benthic data further demonstrated the generally diverse character of the Cordova benthos. Normal classification and sorting of this data according to species similarities (Figure 6) did not delineate species groups characteristic of a particular station type. Species found at outfall stations were also found at other stations. Normal classification analysis and sorting according to station similarities (Figure 7) did not separate the stations into distinct communities with the exception of Station E., and Stations A and C. Station St. E. clearly showed the least similarity to the other stations. Station I, also an outfall station, was not grouped with Station St. E. because several of the species at Station I were also found at other nonoutfall stations. High similarity was only observed between Stations A and C, even though species density, diversity, and richness were considerably different at these stations. Of the 17 species present at Station C, 16 were also present at Station A.

In Figure 7, Stations NEFCO GT and NEFCO N-O, both non-operative outfalls during the 1978 season, are shown to have a diverse benthic community. While the results of the

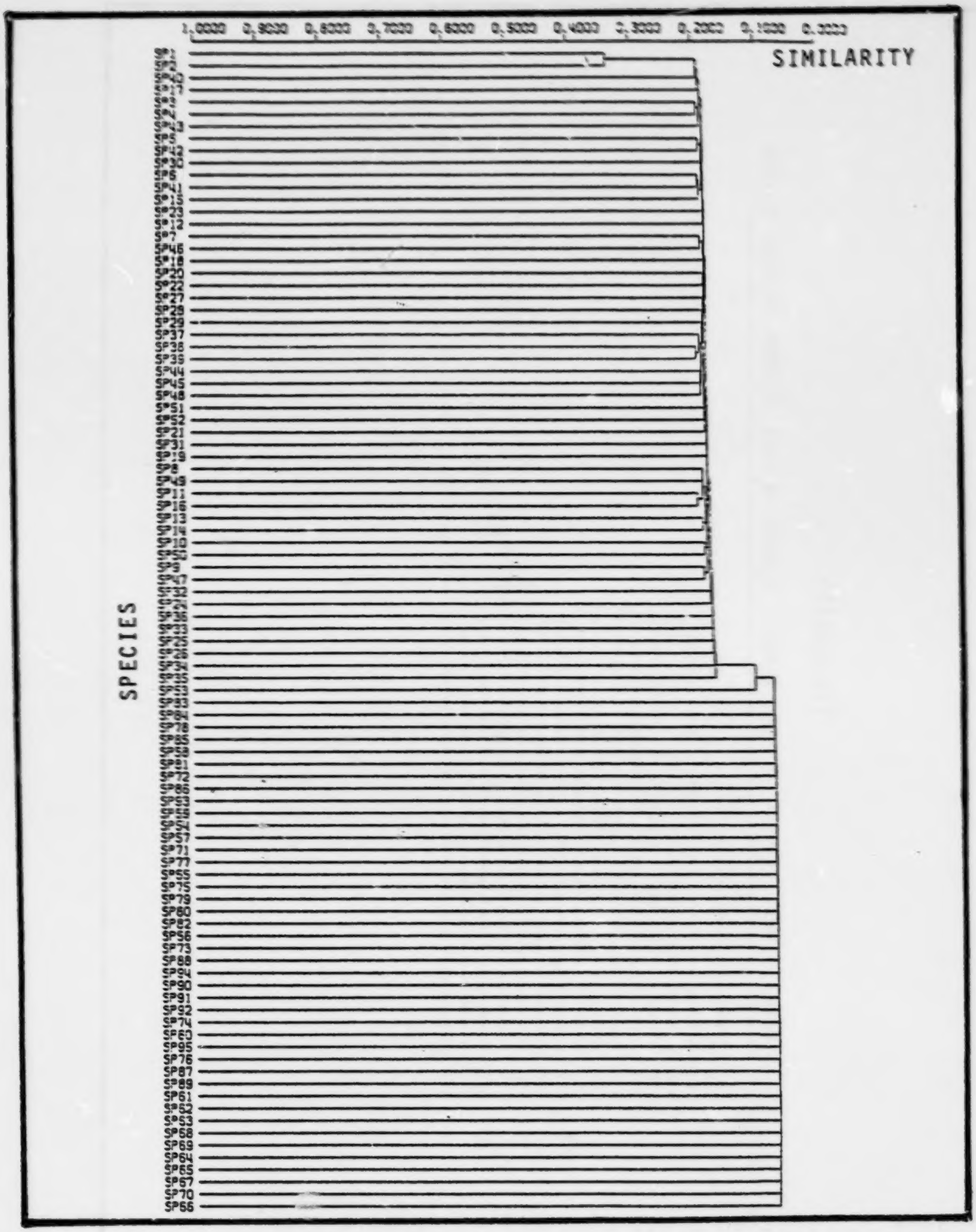


Figure 6. Species group clusters of Cordova samples (1 mm and 0.5 mm screenings).

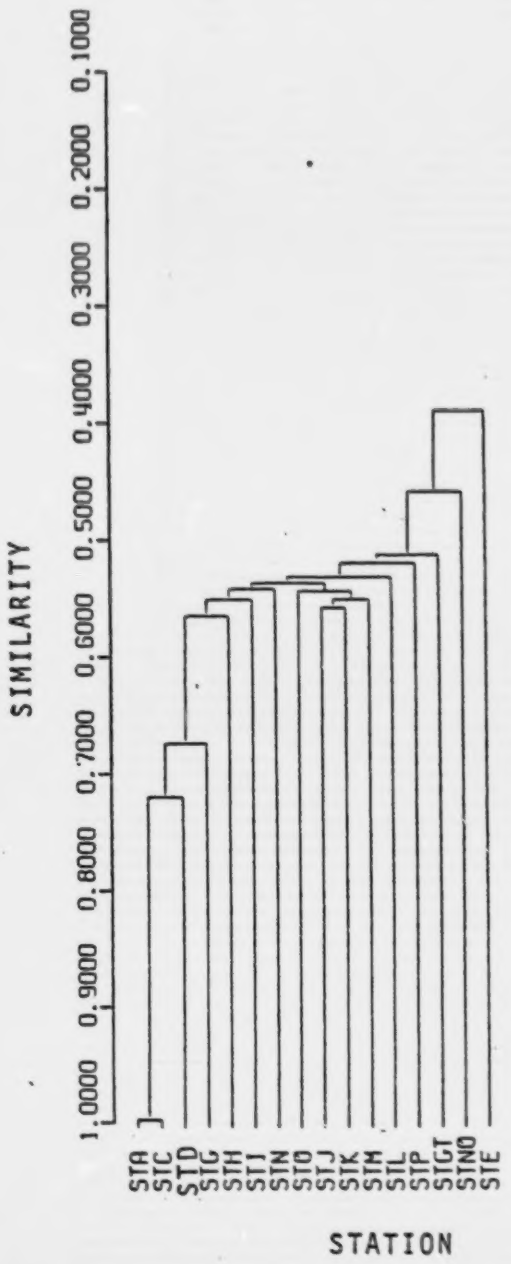


Figure 7. Station group clusters of Cordova samples (1 mm and 0.5 mm screenings).

classification analysis indicated a stable benthic community at the two NEFCO stations, without benthic data from previous years, the present benthic community structure at these sites cannot be interpreted to represent recovery of the benthos from earlier waste discharges.

At Station C, low species diversity and similarity to only one station were recorded. Evaluation of sediment and water quality, and sediment composition data for Station C did not identify a specific factor of factors which were responsible for the observed benthic conditions. At the present time, it appears that some parameter which was not tested in this study is responsible.

Normal classification and data sorting were also performed on the 1 and 0.5 mm data as separate data groups. The species and station similarity dendrograms resulting from these analyses are provided in Appendix 1. Since neither of these separate data sets represented a complete description of the Cordova benthic community, a discussion of these dendrograms was not included in the results and discussion section.

The observed impacts on the benthos at Station St. E., elevated levels of selected water and sediment quality parameters at Stations St. E. and NPP, and the extent of waste accumulation at St. E. and NPP implied that tidal and current flushing at these stations were more restricted than at other stations. Indications of improved waste dispersal accompanied by increased benthic species diversity at Stations I, NEFCO GT, and NEFCO N-0, suggested better flushing of these outfall stations.

Several authors have reported on situations where tidal or current dispersion were important in determining the effects of cannery effluent (3, 4, 6, 7). Beyer, et. al. (6), in their studies at Petersburg, Alaska, found that strong currents flushed most of the wastes from the Petersburg harbor area, but that some temporary accumulations did occur near the cannery discharges. The number of benthic organisms were reduced in these areas of waste accumulation. With the exception of these areas, however, sediment type, tidal level, and the influence of freshwater input to the system from canneries or rain runoff had a more significant impact on the benthic community than did cannery waste effluent.

CONCLUSIONS

The following conclusions are based on analyses of macrobenthos, sediment and water quality, and hydrological conditions at Kenai and Cordova, Alaska. This study was the result of a single ecological survey during July 23 to 27, at Kenai, and July 29 to August 2, 1978, at Cordova.

KENAI

Aesthetics

- Surface water discolorations and accumulations of whole fish heads, tails, and viscera on the riverbank were observed at the Kenai Packers (KP) egghouse outfall and at the base of the KP Wharf during low tide. The accumulations at the egghouse outfall resulted from discharges which occurred above the low water level. The source(s) of the wastes below the wharf was not determined. River and tidal currents, as well as large fluctuations in tidal height appeared to flush the area of these wastes on a daily basis. Downstream transport and deposition of this waste material was not observed. Neither surface discolorations nor waste accumulations were observed at or near the Columbia-Wards Fisheries Cannery (CWF).

Water Quality and Sediment Conditions

- Water quality conditions in the Kenai River were not affected by cannery waste discharges from KP or CWF. Dissolved oxygen values at all depths sampled were generally at or near saturation, and were never lower than 8.5 mg/ℓ at any station. Only salinity varied dramatically and this variation was entirely a function of changes in tidal and river flow.
- Nutrient concentrations in the river water were very low and variations between stations were negligible. In many instances, concentrations were below minimum detection limits for several of the nutrients. Cannery discharges did not appear to have an effect on nutrient concentrations in the water.
- ✓ River configuration, tidal and river currents, and sediment deposition patterns were the principal factors affecting particle size characteristics in Kenai River sediments. The impact of cannery discharges on particle size was negligible.
- Cannery discharges did not affect sediment chemistry with the possible exception of total sulfide at two cannery outfall stations. For the range of total sulfide concentrations observed at all stations, however, the concentration in sediment at these outfalls may not be significant.

Biological Conditions

- Benthic community structure was poorly developed in the Kenai River sediments. At several stations only one species was found and often in very low abundance. The majority of stations had only two species or less; maximum species richness was four, and this occurred at only one station. At all stations, nematodes or oligochaetes were the dominant macrobenthos.

Effects of Cannery Discharges

- Cannery discharges to the Kenai River had no appreciable impact on sediment and water quality, and the macrobenthos. No evidence of persistent waste accumulations at the Kenai canneries was observed. The combined action of tidal currents and large twice-daily variations in tidal height sufficiently flushed the river of seafood processing wastes. While the Kenai River benthic community is poorly developed, attempts to associate cannery discharges to the observed benthic conditions were inconclusive. Limitations on habitat utilization imposed by sediment type, tidal induced scouring and burial by bottom sediments, and daily salinity changes are probably the major factors responsible for low species richness and poor community development.

Aesthetics

- Surface discolorations and floating debris were observed near the St. Elias Cannery Dock (St. E.) and in the vicinity of the North Pacific Processors (NPP) dock.
    - At the St. E. dock, the major aesthetic problem was from floating debris associated with the dumping of whole crab shells and some crab appendages off the center of the dock.
    - At NPP, a whitish-yellowish discoloration of the surface water resulted from intermittent cannery discharges. Patches of floating debris from these discharges were recorded over 45 m from the discharge point.
    - No aesthetic problems were observed at Morpac, New England Fisheries Company (NEFCO), or the nonoutfall stations.

Bottom Accumulations

- Underwater photography identified accumulations of fish and crab wastes around each of the operating cannery outfalls.
    - Whole crab shells and crab appendages had accumulated directly below the center of the St. Elias Cannery dock (St. E.). It appeared that all of the crab wastes had been dumped from the dock. The wastes

extended out from the dock in a semicircle for a distance of 5 m. Maximum pile depth was 25-30 cm. A ✓ few fish heads and crab shells were observed off the end of the cannery outfall which was only 16 m from the crab piles and at one end of the dock.

- At the North Pacific Processor (NPP) outfall, waste discharges have cut a trough approximately 3 m wide and over 6 m long in front of the outfall. The depth of the trough was not determined because of considerable debris in the trough. Diver estimates of the depth of the debris were over 1 m. Numerous fishtails and heads were observed in the trough, although crab exoskeletal wastes were estimated at 90 percent of the waste material. The crab waste averaged 5 cm in size. Discharges from the pipe which occurred during filming did not contain particles the size of those represented in the trough.
- In comparison to the waste debris at St. E. and NPP, processing wastes at the Morpac outfall were more finely ground and more evenly distributed over the bottom. No distinct piles were observed. The wastes were confined to a circular area extending 12-16 m from the center of the discharge. Bottom material in this area consisted of a layer of primarily silt and finely ground fish and crab parts, 15 to 30 cm deep.

- Bottom films of the two discharge areas at the New England Fish Company Cannery (NEFCO) showed no evidence of processing waste accumulations from previous years. The NEFCO cannery was not in operation in 1978.

Water Quality and Sediment Conditions

- o At no stations were there indications of depressed oxygen concentrations. Dissolved oxygen values were generally at or above 10 mg/ℓ .
- o The effects of cannery discharges on nutrient levels in the water were very localized. Considerably higher concentrations of ammonia, organic nitrogen, and sulfide occurred at the NPP outfall and the St. E. dock. Total phosphorus concentrations at the St. E. dock were 2 to 3 times greater than at any other station.
- o Bottom sediment samples obtained from outfall stations showed typically higher total Kjeldahl nitrogen and total sulfide concentrations.
- o Analyses of macrobenthos data indicated a generally stable and very diverse benthic community. The effects of cannery effluents on the benthic community were only observed in a localized area immediately off the St. E. dock. Benthic samples from the NPP outfall were not collected, and no assessment of the impacts of cannery discharges on the benthic community at the NPP outfall was made. At the NPP outfall, the depth and horizontal extent of accumulated fish and crab wastes prevented collection of satisfactory benthic samples. Macrobenthic

conditions at Station C, located approximately 100 m from the St. E. dock were poorer than expected. These conditions, however, could not be clearly associated with the sediments or water quality parameters tested, or with cannery discharges.

Biological Conditions

- Flatfish (halibut and flounder), rays, and other unidentified fish species were attracted to the waste accumulations, often in considerable numbers. Large flatfish (>0.3 m in length) numbering 40 to 50 at any one time during underwater filming, were observed feeding and swimming at the NPP waste trough. Lesser numbers of fish were observed at the St. E., Morpac, and NEFCO outfalls. Very few fish were observed at the mid-channel or control stations. Those which were noted were small (<15 cm in length).
- Seasonal variations in benthic populations and the effects these variations may have on interpretation of the benthic data were not considered. Time constraints did not permit collection of seasonal samples.

Effects of Cannery Discharges

- The effects of cannery discharges on sediment and water quality, and on the macrobenthos were localized in the immediate area of waste disposal. The degree of impact on these parameters appeared to be a function of the degree of flushing occurring at the outfall or, in the case of St. E., the dumping site. Sufficient tidal flushing for dispersal of discharged or dumped wastes did not occur at the NPP outfall or the St. E. dock. Consequently, localized impacts on the above mentioned parameters were observed.

COMPARISON OF ALASKAN SITES

- Hydrological conditions in the vicinity of cannery waste processing outfalls differ considerably. At Kenai, canneries discharge their processing wastes into the Kenai River, a tidal river which experiences twice daily flushing. As a result of this flushing action, there were no apparent problems with persistent seafood waste accumulations, and impacts to sediment and water quality were negligible. A poorly developed benthic community appeared to result from natural rather than man-induced causes. At Cordova, tidal flushing action is poor at three cannery outfall areas; consequently, impacts of processing waste disposal on sediment and water quality, macrobenthos, and waste accumulations are more clearly defined than at Kenai.

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APPENDIX

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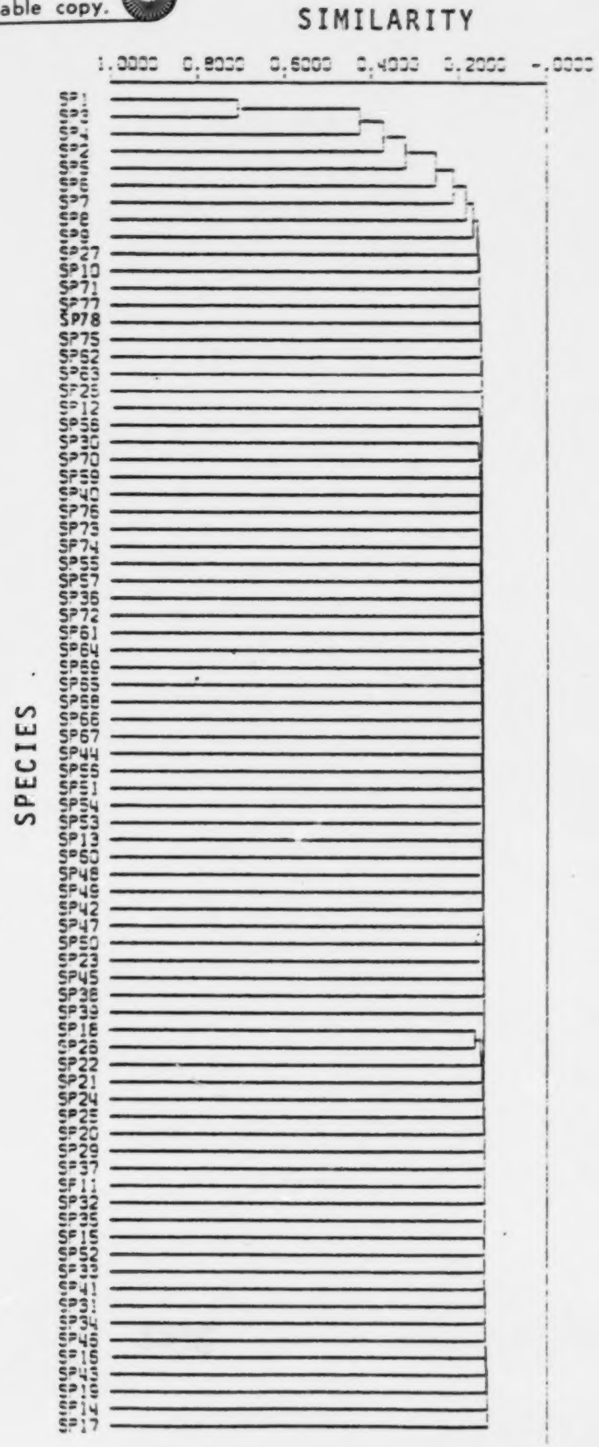
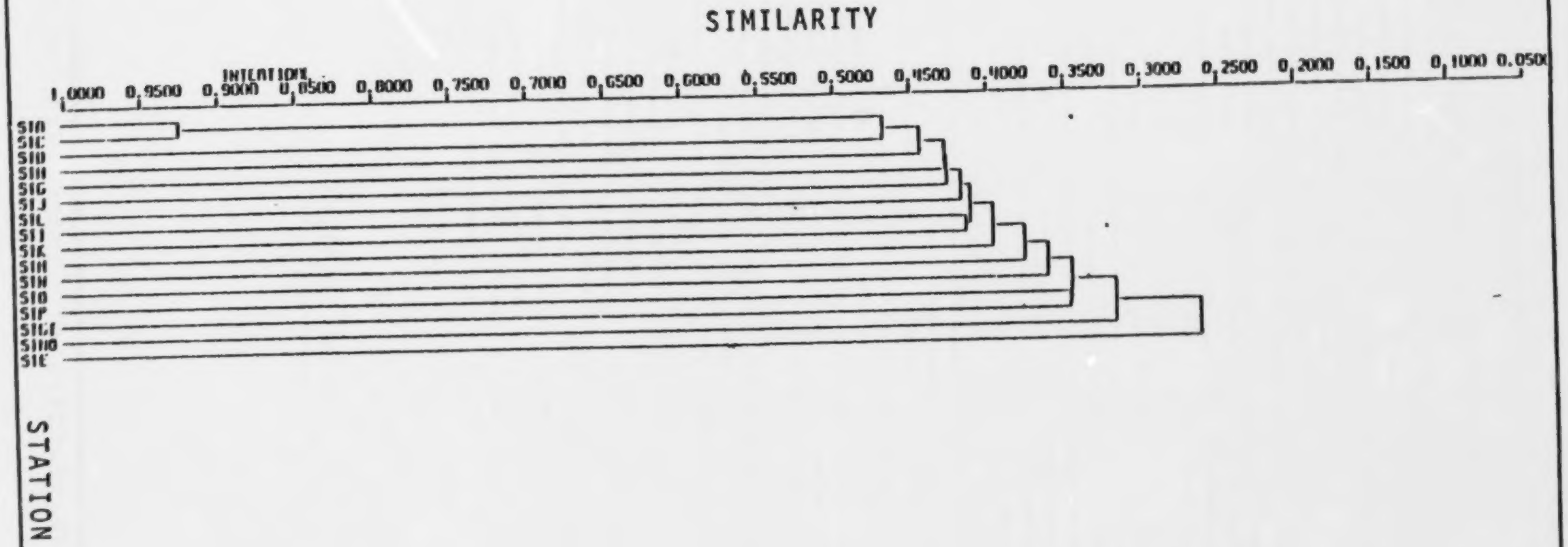
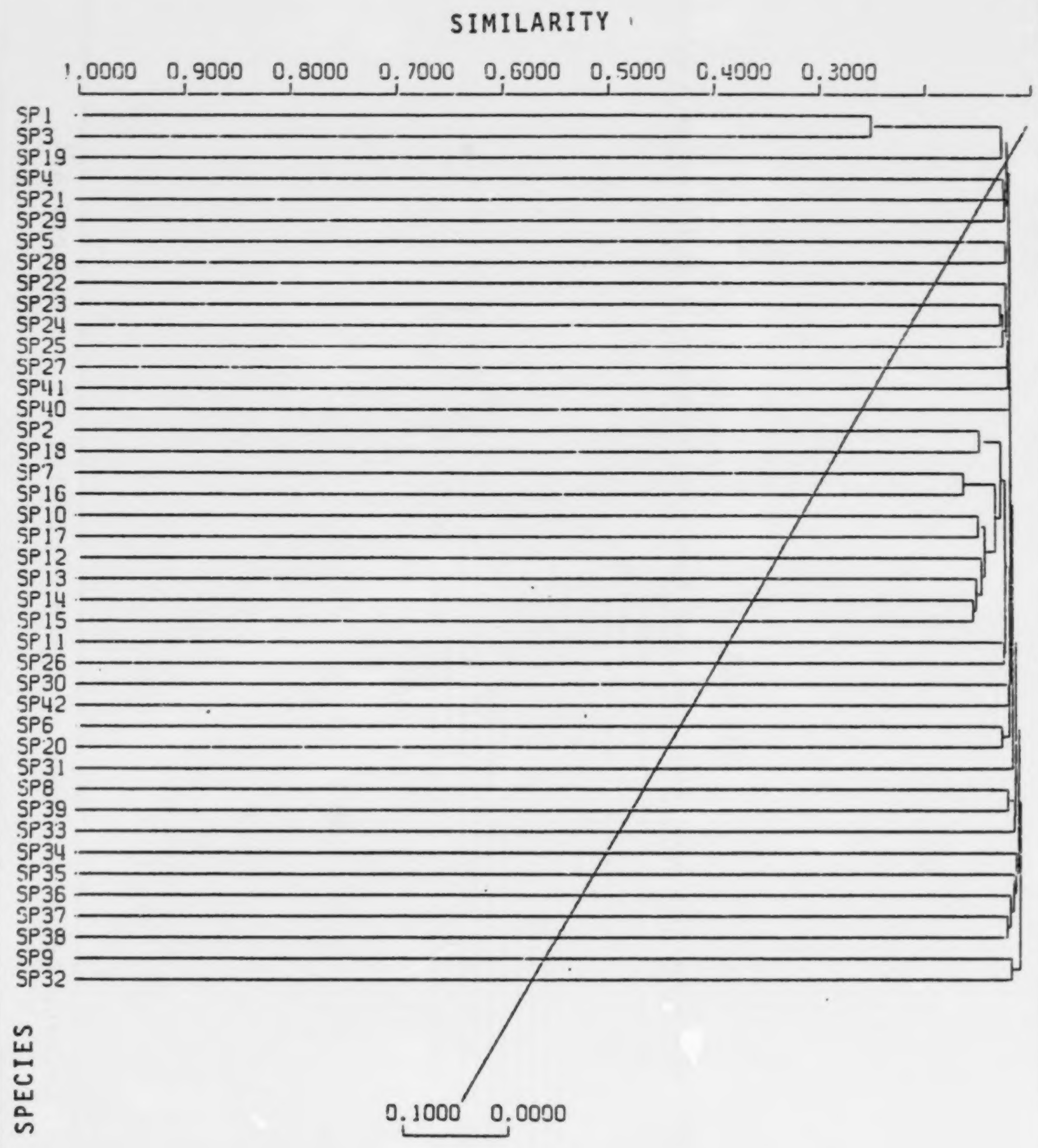


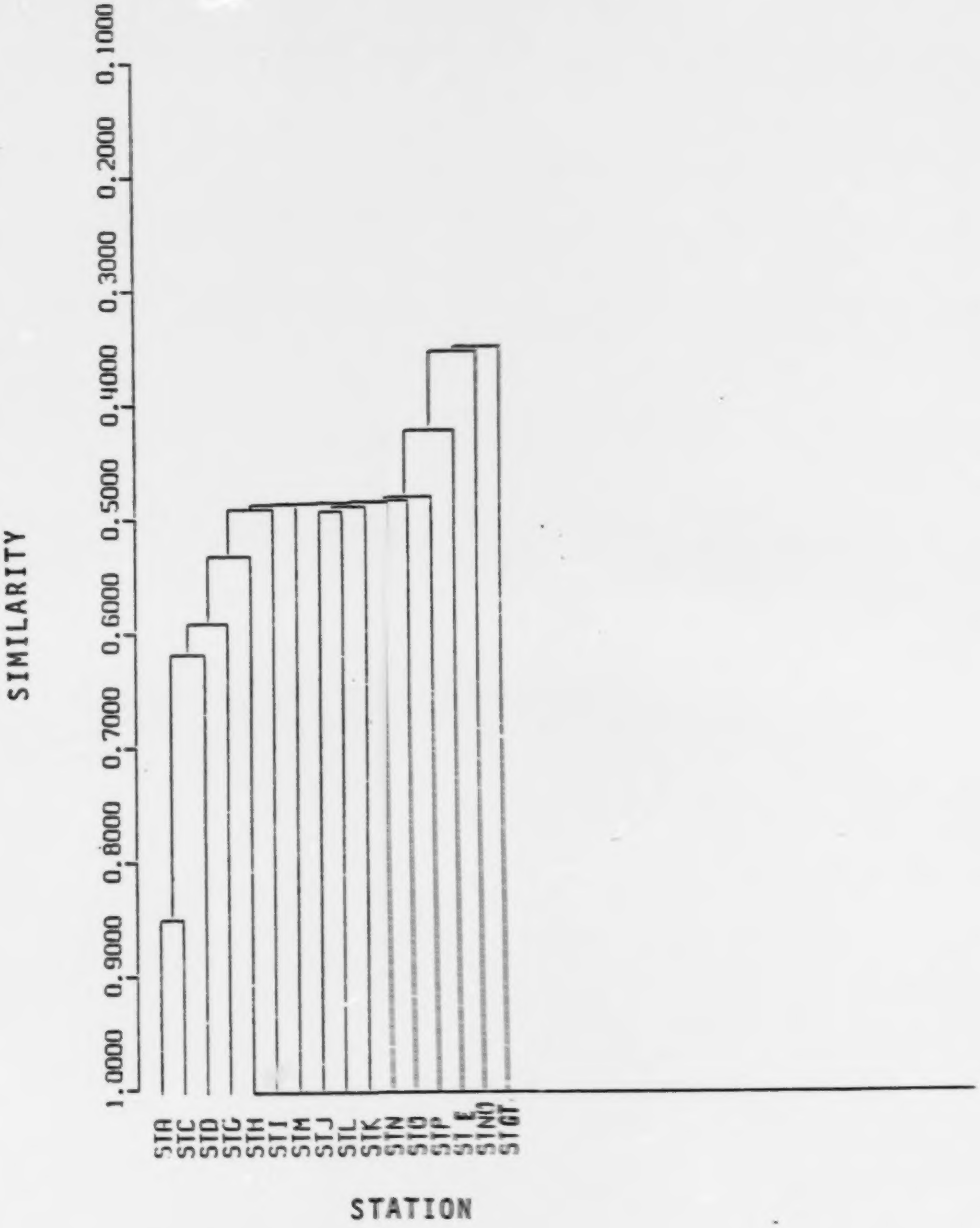
Species group clusters of Cordova samples (1 mm screenings).



Station group clusters of Cordova samples (1 mm screenings).



Species group clusters of Cordova samples (0.5 mm screenings).



Station group clusters of Cordova samples (0.5 mm screenings)

ADDRESS ONLY THE DIRECTOR,
FISH AND WILDLIFE SERVICE

United States Department of the Interior

FISH AND WILDLIFE SERVICE
WASHINGTON, D.C. 20240

In Reply Refer To:
FWS/ES

AUG 31 1979

Mr. Robert B. Schaffer
Director
Effluent Guidelines Division
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Schaffer:

In response to your letter of May 23, 1979, as well as a meeting with Mr. Cal Dysinger of your staff on July 24, 1979, we are providing limited comments on your seafood study. We have reserved comments on the report by Ms. Dorthy Soule. We understand that staff from our Laguna Nigel Field Office will provide separate comments on this report. Our comments will be brief and limited to the Alaska and Oregon reports.

In general, we believe the reports received are based on short-term studies under conditions requiring an extremely fast turnaround time. Furthermore, the reports are limited in scope, appear to have significant oversights and omissions, and in most cases no provisions appear to be made for follow-up studies. These reports tend to make rather broad conclusions regarding environmental impacts which we believe are not in keeping with the character of the studies. An additional report by the National Marine Fisheries Service on Finger Bay in Alaska is enclosed for your information.

Specific Comments:

Under this heading brief comments regarding specific reports are provided.

1. An Investigation of Certain Aspects of Crab Processing Waste Disposal Practices: In Situ and In Vitro Responses of Vibrio parahemolitius and Vibrio anguillarium.

   This report by the University of Alaska is very specialized and limited in scope. It is an excellent investigation of the ability of two marine life intestinal pathogens of the genus Vibrio to survive in the marine environment near seafood processing wastes. However, the substance of the report does not justify its use as an evaluation of the potential for diseases of marine life related to the dumping of seafood processing wastes. Such wastes are ideal breeding grounds for large concentrations of fungi, molds, and other types of decomposers. Many organisms in these groups are well known to be opportunistic parasites which periodically infect marine and freshwater organisms on a large scale. Such groups should be thorougly investigated in any evaluation of seafood dumping sites.

2. Working Papers #EPA 910-8-77-100 and 910-8-78-101: "The Dutch Harbor Studies"

We fully concur with many of the conclusions of report #EPA 910-8-77-100 regarding Dutch Harbor. Seafood wastes are primarily responsible for the adverse conditions observed in Iliuliuk Harbor, inner Iliuliuk Bay, and Dutch Harbor. Investigations by ourselves and others support this conclusion. Referral to other studies of this type suggests that this report does not address the full impact of the discharges of seafood wastes in the bay area. For instance, there was no attempt to analyze for H_2S, a significant environmental by-product of the waste. Certainly the conclusions regarding the elimination of discharges from these areas are appropriate and well supported.

The investigation of the discharges to the west side of the island described in report #EPA 910-8-78-101 appears to be superficial and belie the full impacts which are apparently occurring along the west coast of the island. The fact that decomposition is considerably slower than the rate of addition by the discharges supports this belief. It is also supported by the fact that many of the active discharge pipes were moved during the study period creating adjacent pollution sites of close proximity. The fact that the abandoned sites have significant debris and are totally devoid of life after a period of a year or more would suggest a potential for significant damage near shore by such movement of the pipe. The failure of this report to quantitatively assess the amount of H_2S in these locations or determine the western (seaward) extent of the waste from the discharge pipes also limits the report's value as a tool for assessing impacts of the processing wastes.

3. Benthic Macrofauna, Sediment, and Water Quality Near Seafood Cannery Outfalls in Kenai and Cordova, Alaska.

We believe that the conclusions of the study are somewhat misleading. The report appears to minimize existing problems and fails to address the potential for future problems. Certainly the study at Cordova occurred during a season of minimum productivity and the study was not sufficiently in-depth to justify a solid conclusion that the impacts are of a highly localized nature. Follow-up studies are needed to verify the findings. Extensive sediment analysis should be incorporated in future studies including nutrient loading, H_2S production, and ammonia production. Trends in the ecosystem near the waste sites and down-current from them need to be ascertained before any firm conclusions can be drawn regarding impacts.

Similar weaknesses are found in the Kenai study. Our experts agree that no significant impacts may be demonstrated at Kenai at this time. However, they raise the question of potential significant impacts at Kenai with increased loading from additional plants. A similar argument can be made for the Cordova situation.

In the review of previous Alaskan studies section, there are several summaries which are misleading and in some cases invalid. For example, we cannot accept the analogy to Iliuliuk Bay presented in the summary of the Brickell and Goering studies. The fact that natural loading of dissolved organic nitrogen and ammonia in an estuary where salmon carcasses accumulated after spawning approximates the ammonia values in Iliuliuk Bay does not mean the two situations are truly comparable. A consideration of the total freshwater drainage area discharging into the estuary or bay versus the loading and other constraints of the two systems would be necessary before comparability could be contemplated.

The summary of the Nakatoni and Beyer mortality studies provides another example, since the studies are summarized without noting the fact that chronic exposure and secondary effects are not addressed.

The community analysis procedure discussed in the methodology could prejudice against any rare or endangered species found in the study area. Furthermore, we disagree with their contention on page 36 that using a 0.5 mm instead of a 1.0 mm screen changes the conditions described. The conditions are the same; the refinement of those conditions is what differs. The decision of whether or not to use more refinement is tied directly to comparability with techniques used in other studies. Without comparability, refinement is of no value.

4. Benthic Macrofauna, Sediment and Water Quality Near Seafood Cannery Outfall in Yaquina Bay, Oregon.

This report appears to be better done than the Alaskan reports, but still suffers from the same basic weaknesses. H_2S was not addressed. No effort was made to evaluate the relationship of carcinogenic benzopyrene effects to the presence of the seafood wastes, nor was there an effort to determine the source or other possible interrelationships of the benzopyrenes to seafood processing wastes.

Follow-up studies would be needed for the conclusions of this report to be concrete. In addition, loading evaluations of the marine system in Yaquina Bay should be conducted.

5. Section 74 Seafood Processing Study.

We agree with the report's observed differences between the Alaskan seafood industry and the industry found in the contiguous United States. Furthermore, we concur that the reluctance of other processors in the vicinity by the Alaskan fish meal plants to screen their wastes has contributed to the limited success of the enterprises. The report's observation that allowing plants to continue grinding waste for discharge to the marine environment does not provide the necessary incentive for effective in-plant water and waste management practices is well taken.

The report only addresses the problem of waste reduction processes. We believe that the potential value and feasibility of waste disposal technology should also be addressed by EPA, but have no indication that it has been seriously addressed in connection with this series of reports. One possible disposal technology that might be explored is the use of the collection system in reverse to spread the waste over a large area of ocean to create a more natural situation for its degradation and eliminate its adverse impact.

We trust these comments will be helpful to you in preparing your final report. Since we realize that these reports are mandated by Congress and provide the potential basis for future decisions, we have emphasized their limitations and oversights and how they might affect any conclusions of negative impacts. If there are any additional questions, please contact my staff for clarification.

Sincerely yours,

Michael J. Spear
Associate Director

Enclosure

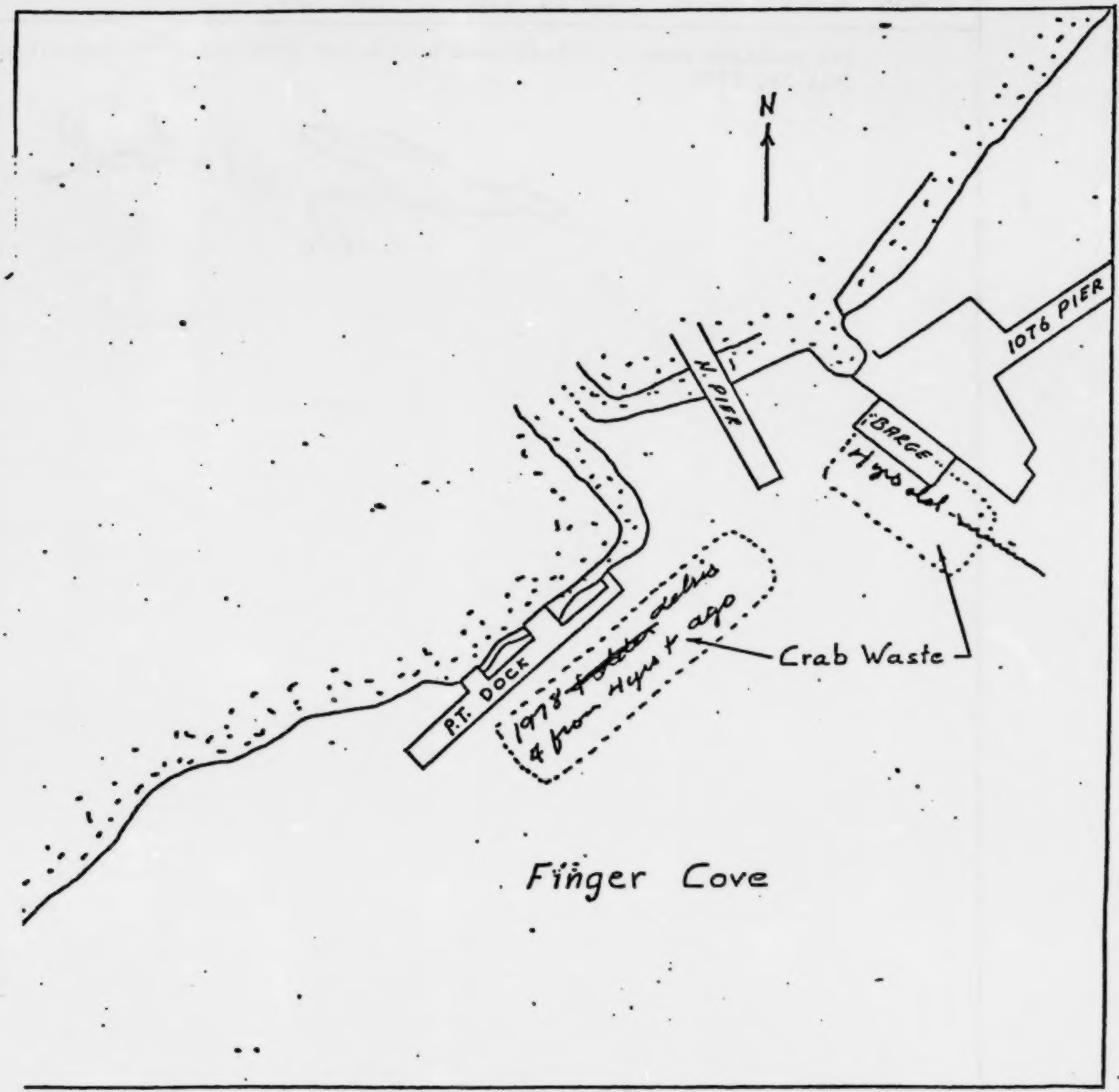
BUREAU OF SPORT FISHERIES AND WILDLIFE

TO:	Director (AE), FWS, Washington, DC ATTN: Roger Griffith	DATE 7/18/79	TIME
FROM:	Deputy Alaska Area Director (AAD-E/ECE) (907) 276-3800, ext. 506	☐ Deliver on regular mail run ☒ Call to have picked up 235-2534	
SUBJECT:	National Marine Fisheries Report - Finger Cove, Alaska		

The enclosed report is faxformed to you per your telephone request of July 16, 1979.

LeRoy W Sowl

INT: 74: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1076 PIER
N. PIER
BARGE
4 yrs old
P.T. DOCK
1978 ~~+ older~~ debris
4 from 4yrs + ago
Crab Waste
Finger Cove

Figure 2. Approximate areas of king crab waste in Finger Cove, Adak Island, on January 17-18, 1979.

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Environmental Assessment Division
Juneau, Alaska

Report of Field Investigations of Finger Cove, Adak Island, January 15-22, 1979

In response to a request from the U.S. Navy, Western Division Naval Facilities Engineering Command, San Bruno, California, the Environmental Assessment Division of the National Marine Fisheries Service investigated Finger Cove by conducting an underwater bottom survey in the vicinity of the existing piers and near the cove mouth.

OBJECTIVES

1. Determine the extent of biological production in terms of epibenthic animals and plants.
2. Locate waste discharged from previous king crab floating processor ships.
3. Delineate area covered by discharged waste.
4. Investigate area in Finger Cove not impacted by crab waste.

METHODS

Duane Petersen and Ron Berg (NMFS) conducted this survey, utilizing SCUBA to obtain underwater observations. Don Garcia and Steve Dehart, U.S. Navy EOD, provided backup diving and surface support. Transportation to and from Finger Cove was provided by a U.S. Navy tug. Underwater pictures were taken of the area surveyed. A transect line, marked in 1-meter (m) intervals, was used to measure widths of waste deposition. Observations of plant and animal life were made while swimming through the area. Substrate composition and depth were noted and recorded. All observations were recorded on underwater writing paper.

Finger Cove is approximately 2 km. long, 183 m. wide at the narrowes part and 460 m. wide at the widest part. Within Finger Cove two are were investigated (Figure 1).

Site 1. This area was surveyed on January 17 and 18, 1979. Exte amounts of king crab waste were found (Figure 2). The waste was ide fiable to parts of king crab legs and claw parts; pieces were foun to 8 cm. in length. The majority of the debris was black decaying organic matter and assumed to be of the same origin. Samples of ea h material were collected and sent to the Environmental Protection Agen Laboratory in Seattle, Washington for analysis.

The only area not covered with organic waste was in front of the Nc t Pier as shown on NAUFAC Drawing No. 6016479. The waste along the P.T Dock and along the west side of the "1076 Pier" ranged from 15-19 m width, and from a trace to over 1 m. in depth.

Natural bottom substrate beyond the waste covered area is hard sand w scattered rocks ranging to 25 cm. in diameter covered with a thin laye of silt. Adjacent to and under the piers the substrate is rocks to 4 cm. in diameter. Attached vegatation was not observed while swimming through the area. Maximum depth was 12 m. Table 1 is a listing of h animals observed during the inner Finger Cove survey.

Site 2. The outer Finger Cove area was surveyed on January 18, 1979. This area is different from the inner cove in three distinct paramet r (1) the substrate is composed of sand and small gravel between outcrop of bedrock to about 12 m. from shore; the bottom then grades into bo l and gravel to 60 m. and beyond; (2) water depth is greater, reaching 2 m. near the midline; and (3) shore-to-shore width is only 38% of the inner cove.

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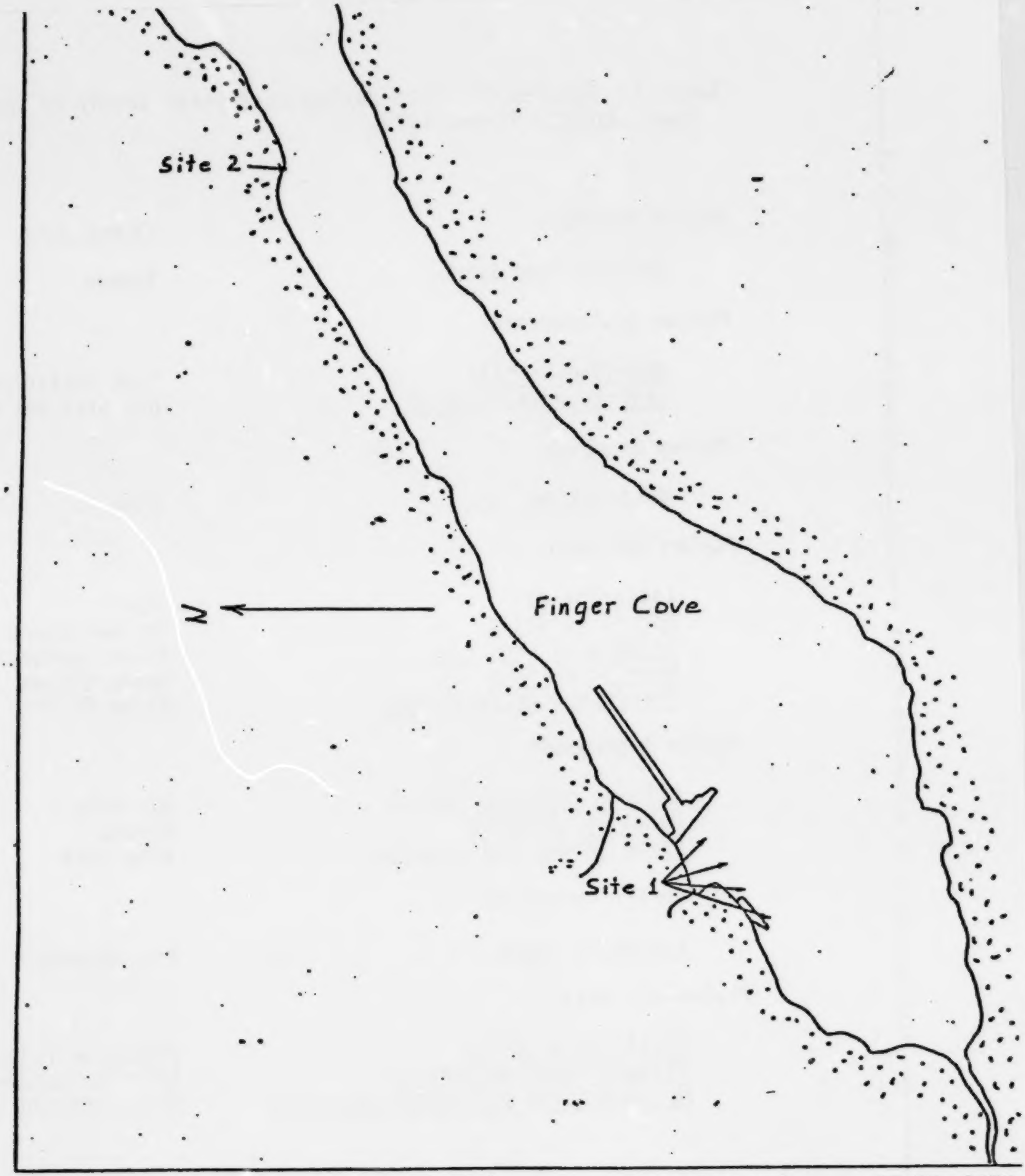
Site 2
N
Finger Cove
Site 1

Figure 1. Areas surveyed in Finger Cove, Adak Island, January 17-18, 1979.

Table 1. Species observed during underwater survey of inner Finger Cove, January 17-18, 1979.

	Common Name
Phylum Porifera	
Unidentified Sponge	Sponge
Phylum Coelenterata	
Metridium senile	Fine tentacled sea anemone
Cribrinopsis fernaldi	Big pink sea anemone
Phylum Annelida	
Unidentified sp.	Worm
Phylum Mollusca	
Littorina sp.	Snail
Dirona aurantia	Golden dirona
Triopha carpenteria	Clown nudibranch
Mopalia muscosa	Mossy chiton
Pododesmus macroschisma	False Pacific jingle
Phylum Arthropoda	
Balanus cariosus (dead)	Barnacle
Pandalus goniurus	Shrimp
Paralithodes camtschatica	King crab
Phylum Echinodermata	
Cucumaria vegae	Sea cucumber
Phylum Chordata	
Phytichthys chirus	Ribbon prickleback
Citharichthys stigmaeus	Speckled sanddab
Myoxocephalus polyacanthocephalus	Great sculpin

Debris from 1978 (1 year ago) and most is from 4 years or more ago.

Crab waste was not located; however, non-organic debris related to fishing activities was found (e.g., rubber boots, rubber gloves, and beverage containers).

Species of algae and animals were observed in greater abundance and diversity (Table 2).

DISCUSSION AND RECOMMENDATIONS

Inner Finger Cove is impacted by large amounts of organic waste materia from previous king crab processing activities. Evidence indicates that the area, at some time perhaps in the past 2-4 years, has turned toxic to attached sessile animals inhabiting the area. Barnacles, a sessile animal covering the piles and debris, were dead. No living barnacles were located in the inner cove. Limpets, snails, small crabs, sponges, and encrusting algae were either absent or extremely rare.

King crab recovery is about 20%. This means that about 176 kg. of every 220 kg. of crab processed is waste. When any dead organic substance exists in water, it decays. The chemicals comprising the body of a dead animal are broken down by a series of bacteria and fungi. The decaying tissue is eventually converted to nutrients which are reused by all living plants and animals present, and to inert (or slowly decaying) residue. Chiton, a good portion of king crab waste, is degraded slowly in seawater.

The effect of the decay process on the water depends on the concentration of material. When oxygen is present in the water, decay is relatively inoffensive; the organisms causing decomposition are types that require oxygen for respiration, and their major products are water-soluble or odorless nitrates, carbon dioxide, and sulfates. If decomposing material becomes highly concentrated, the population of decomposer organisms may place such a demand on the aquatic oxygen supply that it becomes exhausted. Decay will still proceed, but by means of

Table 2. Species observed during underwater survey of outer Finger Cove, January 18, 1979

ANIMALS	Common Names
Phylum Porifera	
Unidentified sponge	Sponge
Phylum Coelenterata	
Metridium senile	Fine tentacled sea anemone
Cribrinopsis fernaldi	Big pink sea anemone
Tealia sp.	Sea anemone
Phylum Mollusca	
Littorina sp.	Snail
Boreotrophon pacificus	Snail
Buccinum glaciale	Snail
Dirona aurantia	Golden dirona
Triopha carpenteria	Clown nudibranch
Mopalia muscosa	Mossy chiton
Pododesmus macroschisma	False Pacific jingle
Mytilus edulis	Blue mussel
Serripes groenlandicus	Greenland cockle
Macoma calcarea	Chalky macoma
Phylum Arthopoda	
Balanus cariosus	Barnacle
Pandalus goniurus	Shrimp
P. danae	Dock shrimp
Elassochirus tenuimanus	Big-clawed hermit crab
Pagurus sp.	Hermit crab
Phylum Echinodermata	
Henricia sp.	Starfish
Strongylocentrotus polyacanthus	Sea urchin
Cucumaria vegae	Sea cucumber
Phylum Chordata	
Myoxocephalus polyacanthocephalus	Great sculpin
ALGAE	
Agarum cribrosum	Sea colander
Alaria crispa	Wing kelp
Fucus distichus	Rockweed
Halosaccion glandiforme	Sea sac
Iridaea cornucopiae	Red algae
Odonthalia floccosa	Sharptooth brush
Rhodymenia palmata	Dulse

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different bacteria, which produce large amounts of nauseating and toxic gasses, such as ammonia, hydrogen sulfide, methane, mercaptan, and cadaverin (Imhoff and Fair, 1956). As a result, all the ordinary aerob flora and fauna of the water are deprived of oxygen and die out. A toxic condition need only last for a few hours to destroy life. Anothe possible cause for the dead barnacles could have been a release of toxi gasses which could advertently affect not only attached life but also any motile animals present. Natural or cyclic mortality was ruled out because of the live attached organisms observed at site 2.

Processing of king crab should not adversely affect Finger Cove if all organic waste material is deposited in the deeper waters off Finger Bay near 51°53'30" N. latitude and 176°28'00" W. longitude. If a large amount of organic waste is deposited within Finger Cove proper, we believe that the area will become unfit for marine life and that the runs of pink and coho salmon in the stream flowing from Betty Lake into Finger Cove could be affected.

The underwater photographs and lab analysis will be forwarded with the proper captions when received.

ACKNOWLEDGEMENTS

LCDR Sam Saltoun, Public Works, met us at the airport and made arrangements for transportation to and from Finger Cove. CWO Art Huffman and crew, EOD, provided equipment and logistics which insured success of the operation.

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Benthic Macrofauna, Sediment and Water Quality near Seafood Cannery Outfalls in Yaquina Bay, Oregon

by

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ABSTRACT

Seafood canneries in lower Yaquina Bay, Oregon process shrimp (Pandalus jordani), Dungeness crab (Cancer magister), a variety of bottom fish and several salmon species. The shrimp wastes are screened and discharged directly into the Bay beneath the cannery docks. During the shrimp processing season about 3.8 million liters of wastes are discharged daily.

We conducted a survey of the macrobenthos, sediment, and water quality in Yaquina Bay in May 1978. The effects of the cannery wastes were restricted to the immediate vicinity of the cannery docks. The effluent plume was quite turbid and had high nutrient concentrations. Because of its initial low salinity it was restricted to the surface layer where it mixed with estuarine water and was rapidly dispersed by strong tidal currents. Dissolved oxygen concentrations were 7.0 mg/l or greater in the plume. The strong currents and screening treatment of the effluent minimized deposition of solids on the sea bed. Bottom water quality was not adversely affected.

A very diverse and abundant macrofaunal benthic community was present along the cannery docks. The community structure of the benthos near the cannery outfalls was very similar to that at the Marine Science Center docks across the Bay. Difference in species composition of benthic assemblages in lower Yaquina Bay were strongly correlated with sediment composition.

INTRODUCTION

The environmental impact of seafood cannery effluents has received relatively little attention by marine ecologists. On the west coast of the United States environmental conditions in the vicinity of cannery outfalls in Los Angeles Harbor have been examined by Soule and Oguri (1976) and Reish (1959); in Dutch Harbor, Alaska by Stewart and Tangarone (1977) and Karna (1978); at Petersburg, Alaska by Beyer, Nakatani, and Staude (1975), and at sixteen Alaskan sites by the Environmental Protection Agency (EPA) (1975). To our knowledge the effects of seafood cannery effluents have never been examined on the Oregon coast.

Section 74 of the Clean Water Act of 1977 (Public Law 95-217) required the EPA to conduct a study of the ecological effects of seafood cannery wastes. As part of that study we have examined biological sediment and water conditions in the vicinity of cannery outfalls in lower Yaquina Bay near Newport, Oregon (Fig. 1). Cannery operations in Yaquina Bay are representative of those throughout the Pacific Northwest. The principal species processed include shrimp (Pandalus jordani), Dungeness crab (Cancer magister), a variety of bottom fish and several salmon species. The shrimp cannery effluents in Yaquina Bay are screened, thus removing crustacean shells.

The macrofaunal benthos was selected as the most appropriate indicator assemblage for determining the effects of cannery effluents because benthic animals are relatively long lived and permanent residents of a given habitat. Thus, they are sensitive to the chronic effects of environmental perturbations. The structure of benthic communities should reflect changes in sediment or bottom water quality that might result from cannery effluents.

Our principal objective was to assess the ecological impacts, if any existed, through a comparison of biological, sediment and water quality at control and cannery sampling sites.

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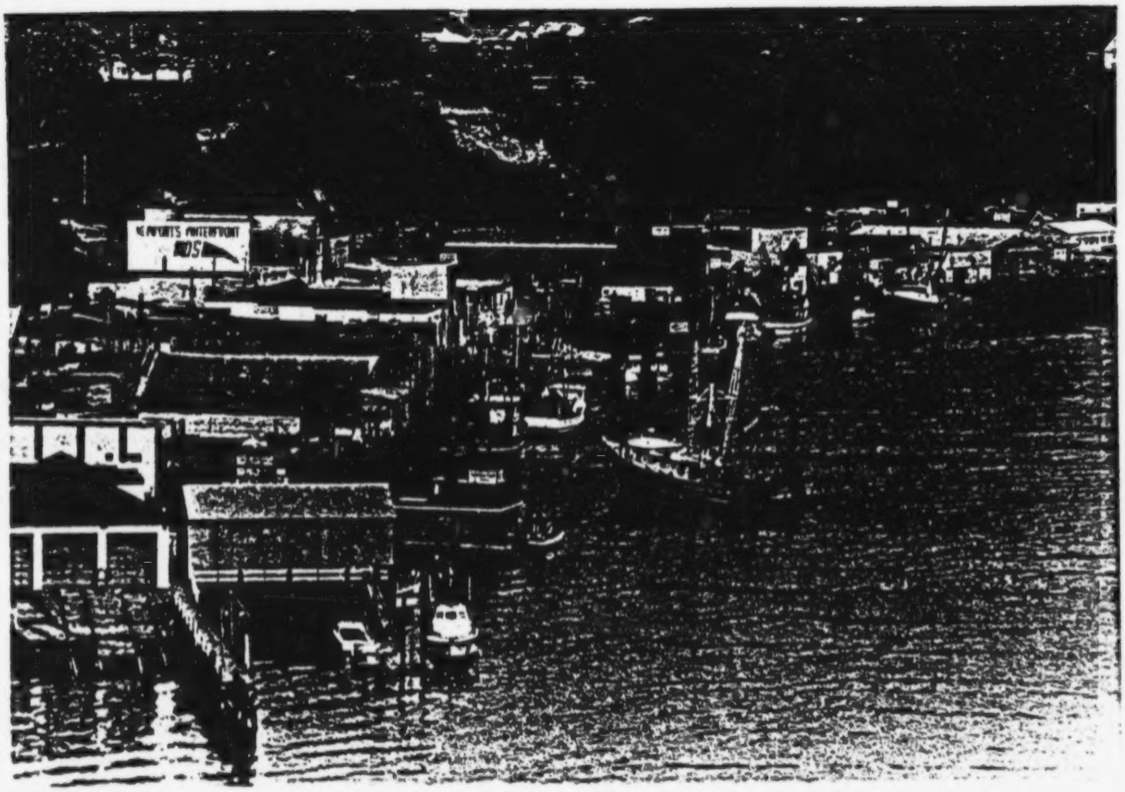

NEWPORTS WATERFRONT

Fig. 1. Cannery row in Yaquina Bay, Newport, Oregon.

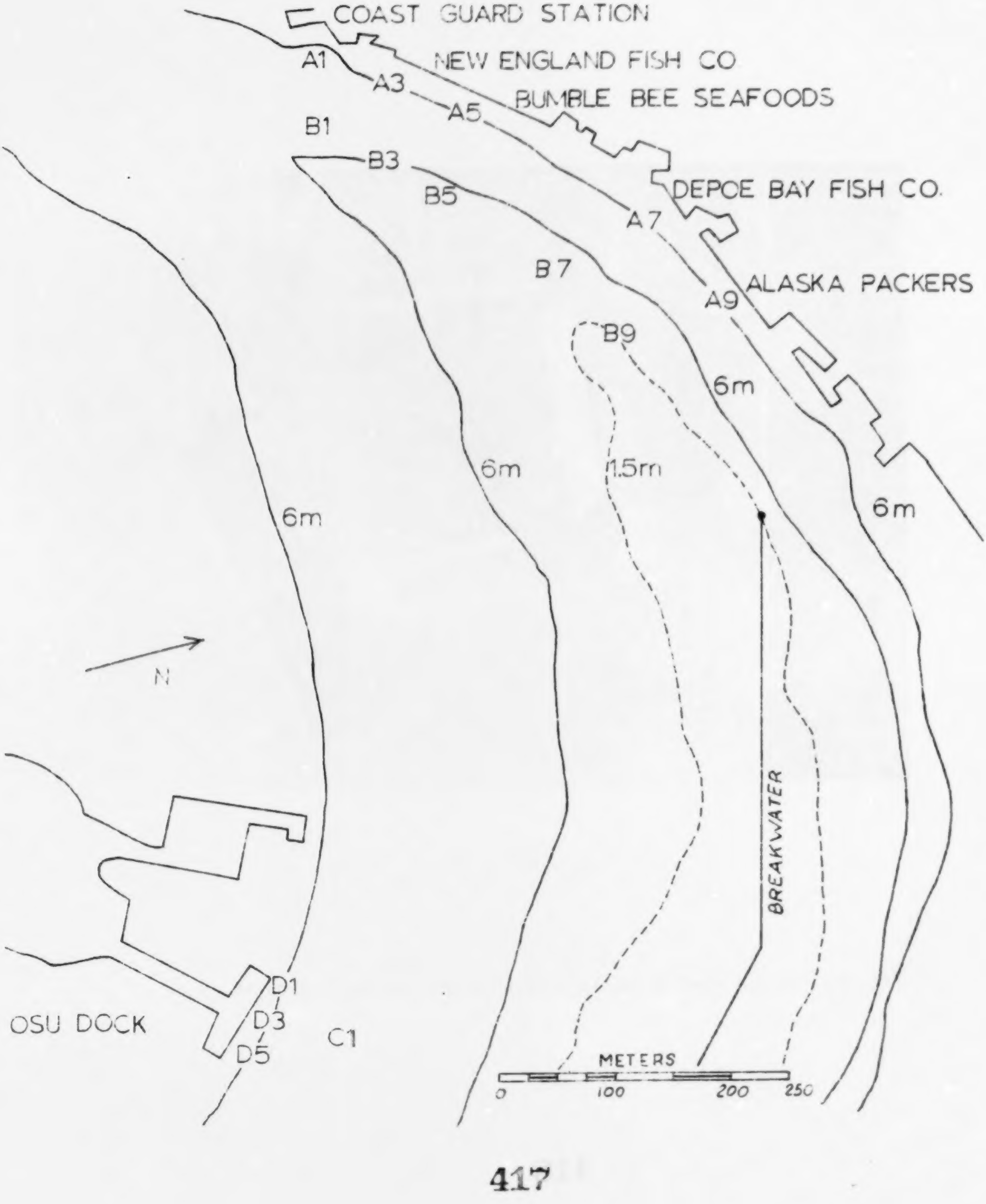
MATERIALS AND METHODS

Stations were located along four transects (Fig. 2). Transect A was immediately adjacent to the docks along cannery row and transect B was parallel to A, 100 m offshore. Five stations were occupied on each of these transects. Transect D included three stations adjacent to the docks for the three oceanographic vessels of Oregon State University. Three stations were originally designated along transect C, 100 m off the OSU docks. However, because of the difficulty in obtaining sediment samples at C, collections were made at only one C station.

The major survey was conducted on 9-10 May 1978. Initially we attempted to collect benthic samples with a 0.1 m^2 Smith-McIntyre grab. Adequate samples could not be obtained with this device because of the shells and coarse sediments found along the A and C transects. Sediment samples were therefore collected with a dredge (mouth: 16.5 x 30 cm, depth: 15 cm, lining: 1 mm mesh screen, (Fig. 3). The dredge was towed for approximately 100 m along the transect to obtain a single sample. Replicate dredge samples were taken at each station for faunal analysis. In the notation used in this report the second replicate collected at the seventh station on transect B is designated sample B7-2. Animals were removed by sieving the sediments through a 1 mm screen, preserved in 10% buffered formalin, later transferred to 70% ETOH, identified to the species level and enumerated. A third dredge sample was taken for sediment chemistry and particle size analyses.

Water samples were collected at the bottom with a 5 l Niskin bottle and at the surface with a bucket. Temperature, salinity, and dissolved oxygen concentration were determined at the surface, 1 meter depth, and bottom with an RS-5 salinometer (Beckman Instr.) and Model 57 DO meter (Yellow Springs Instr.). Surface water clarity was estimated with a standard Secchi disc. Turbidity of the water sample was measured with a Model 2100 Hach turbidi-

Fig. 2. Location of Yaquina Bay stations.


COAST GUARD STATION
NEW ENGLAND FISH CO
BUMBLE BEE SEAFOODS
DEPOE BAY FISH CO.
ALASKA PACKERS
A1
A3
A5
A7
A9
B1
B3
B5
B7
B9
6m
6m
6m
6m
1.5m
N
BREAKWATER
OSU DOCK
D1
D3
D5
C1
METERS
0
100
200
250

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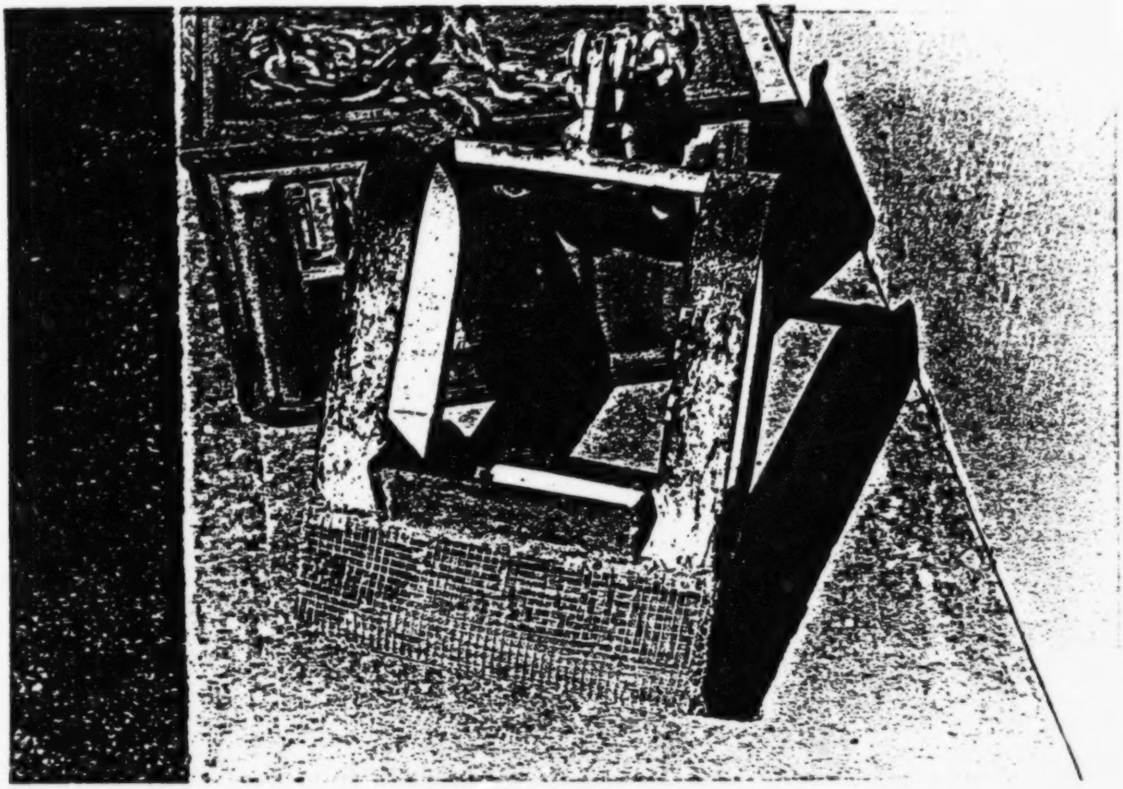

Fig. 3. Dredge used to collect Yaquina Bay sediment samples.

meter and the results expressed in nephelometric turbidity units (NTU).

On 12 May 1978 sediment traps were placed at stations A5, A7, D1 and D5. The traps were aluminum cylinders (diameter 15.2 cm, height 63.5 cm, capacity 11.5 l) covered with a flow straightener. They were strapped to the shoreward side of the most seaward piling beneath the docks. Their bottoms were 1 m above the sea bed. Their contents were retrieved after one week and filtered through a glass fiber filter. The filtrate was preserved with 80 mg/l $H_g Cl_2$ and the residue frozen until the chemical analyses were conducted.

On 18 July 1978 divers collected a second series of sediment samples for physical and chemical analyses. One core sample was taken at each station on transects A and D. The cores were 14 cm deep and 10 cm in diameter.

The sediment particle size distribution was determined for sand by sieving through a Wentworth scale screen series and for the silt-clay fractions by the pipette method (Buchanan, 1971). Sediment samples for bulk chemical analyses were freeze dried and finely ground using a Mullite mortar and pestle. Interstitial water was obtained by centrifuging the sediment under a nitrogen atmosphere at 9000 rpm at 5°C for 10 minutes and filtering the water through a 0.45µ millipore filter. Interstitial nutrients were preserved with 40 mg $HgCl_2$ per liter of sample. Sediment samples for sulfides were collected in 10 cc open barrel syringes; the open end was sealed after sample collection with plastic film and the contents frozen until analyzed. Grease and oil samples were collected in clean (hexane washed) glass bottles with aluminum foil lined lids and kept at 5°C until analyzed.

Bulk organic carbon was determined by subtracting the total inorganic carbon concentration (measured on an OIC model 303 carbon analyzer) from the total carbon concentration (measured on a Hewlett Packard C-H-N analyzer. Sediments for total Kjeldahl nitrogen were digested with H_2SO_4 and persulfate and analyzed with a Technicon autoanalyzer using the automated phenate method (EPA, 1974). Total grease and oil in sediments were determined by the Soxhlet extraction method 502D (APHA, 1975). The hydrocarbon portion of the extracted grease and oil was determined by infrared analysis for hydrocarbons after removal of polar material by silica gel (Method 502E, APHA, 1975). Alkaline soluble sulfide was determined by the method of Green and Schnitker (1974). Total sulfide was also determined by the Green and Schnitker method after the sulfides were liberated with H_2SO_4 and trapped in sulfide antioxidant buffer. Nutrients (organic nitrogen, ammonia, nitrate plus nitrite, total soluble phosphate and orthophosphate) were analyzed on a Technicon autoanalyzer according to EPA methods (1974).

Biological Indices

Specimens which could not be identified to the species level were excluded from the community structure analysis. Replicates taken at each station were not pooled for quantitative faunal analyses. Thus the data set included 28 biological samples. Faunal density was calculated as the number of individuals of all species (N) collected per dredge sample. Areal species richness was estimated as the number of species (S) collected per dredge sample. H' diversity and the complement of Simpson's Index of dominance were calculated as follows:

$$H' = \frac{1}{N}\left(N \log N - \sum_{i=1}^{S} n_i \log n_i\right)$$

$$1 - \text{Simpson's Index} = 1 - \sum_{i=1}^{S} \frac{n_i(n_i-1)}{N(N-1)}$$

where n_i = number of individuals belonging to the i^{th} species.

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The statistical significance of differences in mean values of density, richness, diversity and dominance were tested by analysis of variance and Student-Newman-Keuls multiple range test (Sokal and Rohlf, 1969).

Both normal and inverse numerical classifications were applied to the data set (Boesch, 1977). The normal classification clusters samples on the basis of similarity in the composition and relative abundance of species. Inverse classification clusters species on the basis of similarity in distribution among samples. The distribution and characteristics of the collection and species groups formed by numerical classification can be correlated with environmental factors including stress from pollution.

The classificatory procedures we used are described in detail by Boesch (1977). To reduce the data set to a manageable size, rare species represented by less than ten individuals were excluded from the classification. A square root transformation was applied in both normal and inverse analyses. The Bray-Curtis dissimilarity coefficient (D_{jk}) was used in the normal classification:

$$D_{jk} = \frac{\sum_{i}^{S} |x_{ij}-x_{ik}|}{\sum_{i}^{S} (x_{ij}+x_{ik})}$$

where: D_{jk} = dissimilarity between collections j and k

$x_{ij(k)}$ = square root of the number of individuals of the i^{th} species in the j(k) collection

S = number of species.

Prior to the inverse classification the square root of the abundance of species in each collection was standardized by dividing it by the sum of the square roots of the abundance in all collections. This standardization permits a close affinity between species which differ in abundance but have similar distributions among the collections. The Manhattan metric dissimilarity coefficient (D_{ab}) was used in the inverse classification:

$$D_{ab} = 1/2\sum_{c}^{E}|x_{ca}-x_{cb}|$$

where: D_{ab} = dissimilarity between species a and b

$x_{ca(b)}$ = standardized square root of the abundance in the c^{th} collection of species a(b)

E = number of collections.

Once the matrix of dissimilarity values is generated, the collections (or species) are clustered to form a dendrogram. In this process all entities beginning with the least dissimilar are combined in an hierarchial fashion. This procedure requires a sorting strategy to determine the dissimilarity between a newly combined pair of entities and all other entities remaining in the matrix. The method we used is the flexible sorting strategy of Lance and Williams (1967):

$$D_{hk} = 0.625(D_{hi}+D_{hj})-0.25D_{ij}$$

where: entities i and j are fused to form group k

D_{hk} = dissimilarity between group k and entity h

$D_{hi(j)}$ = dissimilarity between entities h and i(j) in the matrix prior to fusion of i and j

D_{ij} = dissimilarity between i and j before they were combined.

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Relationships between collection groups and species groups can be examined in two-way tables in which the original data matrix is reduced according to the normal and inverse classification results. We calculated the mean number of individuals of each species group within the samples of each collection group. We also determined the constancy of each species group in each collection group. Constancy is the observed number of occurrences of a species group in a collection group divided by the number of possible occurrences. Thus, if a species group includes 6 species and a collection group has 5 samples, 30 occurrences are possible. If every species occurs in every sample, the constancy index would be 1.0. If none of the species occur in the collection group, the index would be 0.

RESULTS

Cannery Effluents

The principal species processed by seafood canneries in Yaquina Bay are shrimp (*Pandalus jordani*), Dungeness crab (*Cancer magister*), a variety of bottom fish, and several salmon species. By July 1977 all of the Yaquina canneries had installed forty mesh screens which retain fish carcasses and shrimp and crab shells. These materials are used either as agricultural fertilizer or mink food. The canneries are constructed on docks and the effluent passing through the screens is discharged directly into the bay beneath the docks.

Although the canneries operate throughout the year, the effluent volume increases substantially during the shrimp season, April to October. During the 1978 season the Yaquina canneries operated fourteen machines for peeling shrimp, two at the New England Fish Co. near station A3, and four each at Bumble Bee Seafoods (A5), Depoe Bay Fish Co. (A7), and Alaska Packers Association (A9) (Fig. 2). At peak production approximately one million gallons (3.8×10^6 l) of shrimp processing effluent are discharged each day into Yaquina Bay. The BOD of this effluent is 1000-1500 mg/l (David Ertz, pers. comm.).

The shrimp processing effluent resulted in a patchy, whitish discoloration of the water beneath the docks along the bayfront and extending a short distance (10-30 m) into the bay (Fig. 4). This plume was most evident during slack water and was rapidly dispersed by tidal currents which are rather strong (100 cm/sec) in the vicinity of the canneries. Because of its buoyant freshwater nature, the plume was restricted to a relatively thin (<1 m) surface lens. During our surveys we observed large numbers of small fish (probably whitebait smelt, *Allosmerus elongatus*) apparently filter feeding within the plume.

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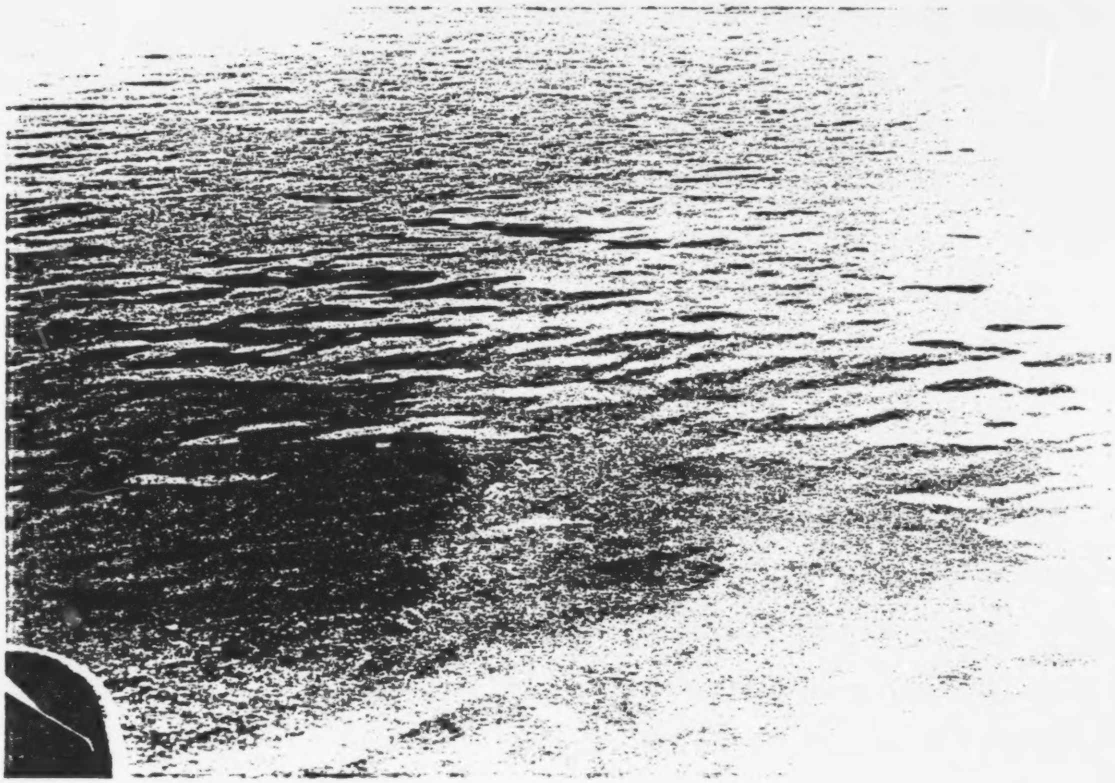

Fig. 4. Seafood cannery effluent plume in Yaquina Bay.

Water Quality and Depth

Stations A1, B1, and C1 were located in channels and were deeper (8 - 13 m) than the other stations (3.5 -6.5 m) (Fig. 2, Table 1). Stations B3 and B5 were at the edge of the channel. Stations B7 and B9 were out of the channel and very near an eelgrass (*Zostera marina*) bed.

The discoloration of the surface water was evident in secchi disc depths and surface turbidity (Table 1). At transect B, C, and D secchi disc depths ranged from 1.25 to 1.60 m. The secchi depth at stations A1, 3, 7, and 9 ranged from 0.83 to 1.17 m. The highest secchi depth of the survey (1.78 m) was recorded at station A5, indicating the patchy nature of the effluent plume. Surface turbidity showed exactly the same pattern as the seccni depths (Table 1). However, turbidity in bottom water along the A transect (1.3 - 2.1 NTU) was actually less than along the B, C and D transects (2.1 - 3.9 NTU) (Table 1). This reflects the restriction of the plume to the surface layer.

There was very little difference between the four transects in salinity and temperature at the surface, 1 m, and bottom (Table 1). Salinities ranged from 25.4 °/₀₀ on the surface at C1 to 33.4 on the bottom at A3. Temperature ranged from 13.2°C on the surface at A9 and C1 to 10.0°C on the bottom at A1 and A3. At most stations the bottom water salinity was 2 - 3 °/₀₀ greater and the temperature 1-2°C less than at the surface indicating slight stratification of the water column. A slight depression in surface salinity due to the cannery effluents is evident from a comparison of the difference in salinity between the surface and 1 m (Table 1). This difference was considerably higher along the A transect ($\bar{x}$ = 2.1 °/₀₀, range : 0.9 to 3.8 °/₀₀) than at the B, C, and D transects ($\bar{x}$ = 0.5, range : -0.1 to 1.4 °/₀₀). The dissolved oxygen concentration was $\geq$ 7.0 mg/l at all stations and depths

Table 1. Water quality and depth at the Yaquina Bay stations.

Parameter		Station													
		A1	A3	A5	A7	A9	B1	B3	B5	B7	B9	C1	D1	D3	D5
Depth (m)		8.0	5.5	5.5	3.5	4.0	13.0	6.5	4.0	4.5	4.5	10.5	5.0	6.5	6.0
Salinity (°/oo)	Surface	30.2	27.1	29.1	26.4	26.1	27.1	26.6	26.1	26.2	26.0	25.4	29.4	26.1	27.8
	1 m	31.6	30.9	31.0	28.6	28.1	27.4	27.1	26.6	26.7	26.5	26.8	29.3	26.9	27.7
	Bottom	33.0	33.4	32.4	28.6	30.1	31.1	30.2	29.4	30.2	31.1	31.2	30.4	29.9	28.3
Temperature (°C)	Surface	12.2	12.8	12.3	12.8	13.2	12.9	13.0	13.1	13.1	13.1	13.2	12.2	13.0	12.8
	1 m	11.4	11.9	11.7	12.5	12.7	12.8	12.9	13.0	12.9	12.9	13.0	12.4	13.0	12.8
	Bottom	10.0	10.0	10.8	12.5	12.0	11.4	11.8	12.2	11.8	11.6	11.8	12.0	12.1	12.5
Dissolved Oxygen (mg/l)	Surface	7.2	7.2	7.9	7.0	7.9	8.2	8.2	8.3	8.2	8.4	8.5	8.2	8.4	8.3
	1 m	7.3	7.2	7.7	7.1	7.9	8.2	8.1	8.1	8.0	8.2	8.3	8.0	8.2	8.2
	Bottom	7.4	7.3	7.8	7.3	7.9	7.7	7.9	8.0	7.8	7.9	7.7	7.8	7.7	8.1
Secchi Depth (m)		1.17	1.07	1.78	0.83	1.06	1.59	1.60	1.53	1.57	1.56	1.45	1.38	1.33	1.25
Turbidity (NTU)	Surface	3.8	3.7	1.5	140.0	8.0	2.5	2.4	2.4	2.4	2.1	2.5	3.5	3.3	3.5
	Bottom	2.1	2.1	2.0	1.3	1.6	2.5	2.4	2.3	2.5	2.4	3.0	3.9	3.6	3.5
Organic Nitrogen (mg/l)	Surface	6.18	2.68	3.30	88.74	3.84	0.14	0.12	0.21	0.15	0.12	0.19	0.15	0.24	0.23
	Bottom	0.20	0.24	0.13	0.59	0.28	0.20	0.16	0.19	0.20	0.16	0.26	0.18	0.46	0.29
Ammonia (mg/l)	Surface	0.37	0.14	0.13	3.46	0.24	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Bottom	0.04	0.08	0.03	0.06	0.04	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.04
Nitrate + Nitrite (mg/l)	Surface	0.16	0.17	0.18	0.31	0.18	0.17	0.18	0.18	0.18	0.19	0.20	0.13	0.19	0.14
	Bottom	0.14	0.12	0.12	0.15	0.14	0.15	0.12	0.12	0.15	0.17	0.14	0.11	0.12	0.16
Total Phosphate (mg/l)	Surface	0.48	0.21	0.26	6.23	0.39	0.06	0.08	0.04	0.04	0.05	0.06	0.09	0.08	0.06
	Bottom	0.05	0.10	0.07	0.12	0.09	0.04	0.06	0.04	0.07	0.06	0.06	0.09	0.09	0.06
Orthophosphate (mg/l)	Surface	0.37	0.16	0.17	5.72	0.29	0.04	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.04
	Bottom	0.05	0.05	0.05	0.06	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.04	0.04

(Table 1). DO concentrations at the surface were slightly less along the A transect (7.0 - 7.9 mg/l) than at the B, C and D transects (8.2 - 8.5 mg/l). This difference was less pronounced at 1 m and on the bottom.

The surface concentration of organic nitrogen along the A transect (2.7 - 88.7 mg/l) was more than an order of magnitude greater than surface values at the other transects (0.11 - 0.24 mg/l) (Table 1). However, organic nitrogen concentration at the bottom was very similar at the A (0.13 - 0.59 mg/l) and B, C, and D transects (0.16 - 0.45 mg/l). This same pattern was found for ammonia, total phosphate and orthophosphate (Table 1). Except for the surface concentration of nitrite plus nitrate at station A7 (0.31 mg/l), there was very little variation in this parameter between stations although surface concentrations (0.13 - 0.22 mg/l) were slightly higher than at the bottom (0.11 - 0.17 mg/l).

Sediment Characteristics

Particle Size Distribution

There were substantial differences in the particle size distribution of sediments between and within transects (Table 2). With the exception of samples A1 and A9. sediments along the A transect were poorly sorted and contained a much larger proportion of coarse sands and larger particles (> 20%) than any of the samples collected on the B and D transects. A particle size analysis was not conducted for the sample from the C transect because it contained only large shells and gravel. The only samples with a large proportion (> 40%) of very fine sands or smaller particles were collected at stations B7 and B9. The other samples collected on the B transect were very well sorted fine sands. The D transect sediments were characterized by a large proportion of both fine and medium sands. Human artifacts on the bottom along the A transect were much more numerous than at any of the other stations (Fig. 5).

Table 2. Mean size distribution (percent weight) of Yaquina Bay sediment samples.

	Station												
Size Class	A1	A3	A5	A7	A9	B1	B3	B5	B7	B9	D1	D3	D5
Coarse sands or larger	8.5	62.4	51.5	21.8	2.9	0.5	0	0	0.8	1.2	3.7	7.2	3.2
Medium sands	11.8	10.5	6.2	35.2	27.0	16.1	17.7	9.2	2.4	3.1	23.8	42.0	44.6
Fine sands	73.9	23.6	26.6	34.8	55.9	83.1	79.4	87.0	54.5	39.4	63.0	47.4	49.4
Very fine sands or smaller	5.8	3.5	15.7	8.2	14.3	0.4	3.0	3.7	42.3	56.3	9.6	3.4	2.8

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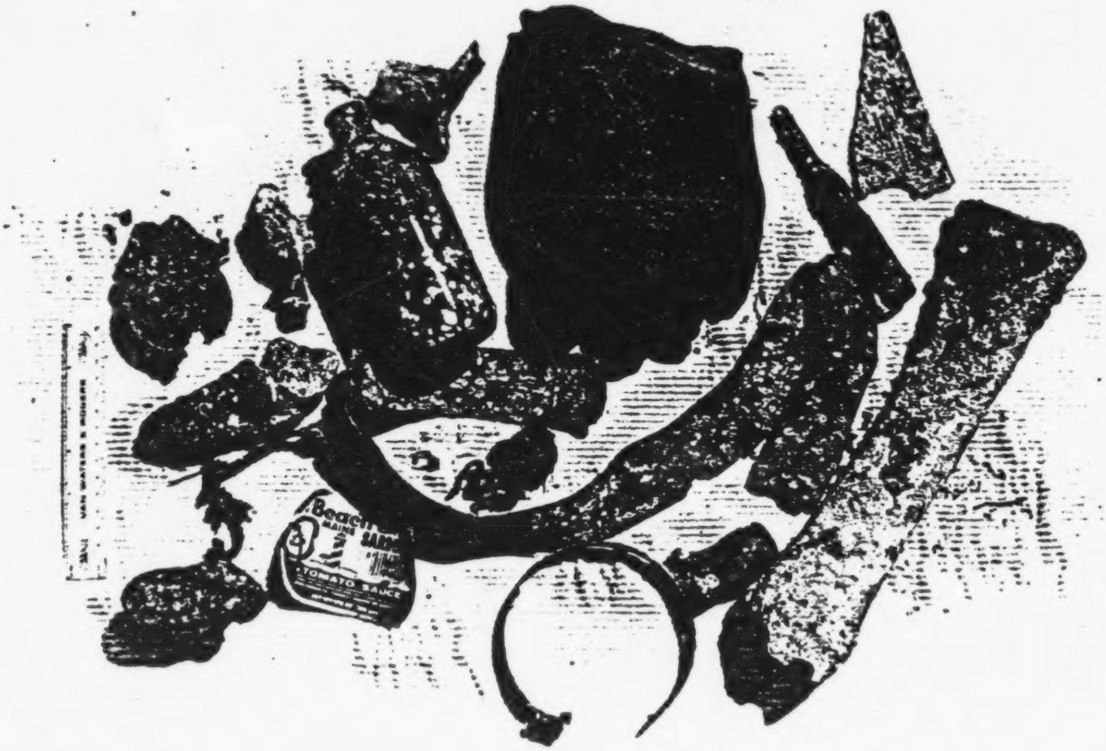

TOMATO SAUCE

Fig. 5. Human artifacts collected in one dredge sample at Yaquina Bay station A3.

Sediment Chemistry

The results of the chemical analyses performed on sediments collected by dredging and by divers are given in Tables 3 and 4 respectively. Comparison of values between these tables may not be valid because of the difference in collection technique. There was no evidence for a major increase in the concentration of any chemical parameter along the A transect. Concentrations of organic nitrogen, nitrate plus nitrite, and total soluble phosphate in interstitial water at station A9 were within the ranges recorded at the B and D transects. Interstitial concentrations of ammonia and orthophosphate at A9 were slightly higher than in the B and D samples. Organic carbon concentrations in bulk sediment samples were inversely related to particle size and reached a maximum at station B9. Total Kjeldahl nitrogen and total oil and grease concentrations were relatively high along the A transect although the ranges overlapped values for the B and D samples. With few exceptions, concentrations of hydrocarbon oil and grease, total sulfides and alkaline soluble sulfides were higher in the A samples.

Characteristics of the material deposited in the sediment traps placed on pilings under the dock opposite stations A5, A7, D1, and D5 are given in Table 5. The greatest weight of sediment was found in the traps at A7 and D5. The concentration of total nitrogen and organic carbon was slightly greater in the residue collected at A5. The organic nitrogen content of the filtrate was similar in all samples. Nutrients were higher in the filtrate obtained from traps on the A transect.

Macrobenthos

Density, Diversity, and Species Composition

The structure of the benthic assemblage was very similar at each of the four transects (Table 6). Analysis of variance showed no significant

Table 3. Chemical analyses of sediment samples collected by dredging, 10 May 1978.

Parameter	Station A9	B1	B3	B5	B7	B9	D1	D3	D5
Interstitial water (mg/l)									
Organic nitrogen	1.27	0.62	0.00	0.88	5.59	1.43	5.01	5.40	2.31
Ammonia	2.89	0.63	1.26	1.70	2.48	1.91	1.96	2.28	1.31
Nitrate + nitrite	0.23	0.25	0.25	<0.05	0.23	0.10	0.22	0.18	0.25
Total soluble phosphate	0.65	<0.25	<0.25	0.37	0.52	0.42	0.77	0.40	0.26
Orthophosphate	0.45	0.15	0.26	0.28	0.36	0.39	0.17	0.25	0.18
Bulk sediment (mg/kg)									
Total organic carbon	3900	<2000	<3100	<2600	12450	29300	5640	1900	<1000
Total Kjeldahl nitrogen	2100	<200	<200	<500	1300	2300	710	1000	<200
Total oil/grease	790	770	180	420	490	290	380	650	22
Hydrocarbon oil/grease	100	180	<5	19	<5	<5	14	43	28
Total sulfides	360	<1	<2	18	95	31	29	12	15
Alkaline soluble sulfides	8	0	0	<2	4	3	3	2	<1

Table 4. Chemical analyses of sediment samples collected by divers, 18 July 1978.

	Station							
Parameter	A1	A3	A5	A7	A9	D1	D3	D5
Bulk Sediment (mg/kg)								
Total organic carbon	5400	5600	18100	9500	-	12200	12700	3400
Total Kjeldahl nitrogen	440	1250	1700	650	2900	520	<125	<100
Total oil/grease	1950	2120	2110	6620	3590	560	560	4060
Hydrocarbon oil/grease	123	230	554	261	219	79	93	107
Total sulfides	330	700	810	1400	520	350	19	23
Alkaline soluble sulfides	6	11	12	24	27	16	3	2

Table 5. Chemical analyses of Yaquina Bay sediment trap samples.

Parameter	Station A5	Station A7	Station D1	Station D5
Residue				
Weight (gm)	36.2	141.3	21.4	88.3
Total nitrogen (gm/kg)	7.4	6.1	6.2	6.3
Total organic carbon (gm/kg)	52.2	44.1	39.9	41.5
Filtrate (mg/l)				
Organic nitrogen	0.24	0.20	0.27	0.18
Ammonia	0.69	0.76	0.07	0.10
Nitrate + nitrite	0.08	0.14	0.06	0.06
Total phosphate	0.31	0.10	0.05	0.05
Orthophosphate	0.29	0.08	0.04	0.04

Table 6. Mean richness, density, dominance, and diversity of benthic samples at Yaquina Bay transects.

Parameter		Transect				Analysis of Variance
		A	B	C	D	
Areal Richness	$\bar{x}$	33.1	31.3	32.0	36.5	F = 0.23 n.s.
(S/Dredge)	Range	10-50	11-53	24-40	29-48	
Density of Individuals	$\bar{x}$	385.3	711.0	129.5	255.2	F = 3.35*
(N/Dredge)	Range	30-842	43-1283	78-181	104-382	
Dominance	$\bar{x}$	0.85	0.81	0.91	0.89	F = 1.64 n.s.
(1-Simpson's Index)	Range	0.74-0.91	0.54-0.93	0.89-0.92	0.82-0.91	
Diversity	$\bar{x}$	1.04	0.94	1.21	1.20	F = 3.18*
(H')	Range	0.84-1.19	0.49-1.18	1.13-1.28	1.08-1.37	

n.s. not significant; $^{*}F_{0.05(24,3)} = 3.01$; $^{**}F_{0.01(24,3)} = 4.72$

differences in either areal species richness or dominance between the four transects. The mean number of species collected in a dredge sample varied between 31.3 at transect B and 36.5 at transect D. Values for the complement of Simpson's Index varied between 0.81 at transect B and 0.91 at transect C. The range for both of these parameters was much greater at transects A and B than at C or D, indicating greater heterogeneity in benthic community structure at the stations closest to cannery row.

Significant differences were observed between the four transects for mean values of both density of individuals and H' diversity (Table 6). The mean density at transect B (711.0 individuals/dredge) was statistically greater than at any of the other transects. Although the mean density at transect C (129.5) was substantially less than at A (385.3) or D (255.2), the difference was not significant. Mean H' diversity at B (0.94) was signigicantly less than at D (1.20), but not significantly different from H' at C (1.21). This apparent contradiction is due to the sensitivity of the multiple range test to differences in sample size which was greater at D than at C. There were no other significant differences in mean H' between the transects.

The similarity in the structure of the benthic assemblage is also reflected in the nearly ubiquitous presence of dominant species among the four transects. Table 7 includes all species which ranked within the ten most abundant species at any one of the four transects. Of the 24 species selected by this criterion, all 24 were found at transect B, 22 at both B and D, and 21 at C. Despite this ubiquitous pattern, no single species ranked within the 10 most abundant species at all four stations. The differences between the transects are obviously due to the relative abundance of dominants rather than qualitative differences in species composition.

Table 7. Mean density of species which ranked within the ten most abundant species at one or more Yaquina Bay transects. Ranks are given in parentheses.

	Transect			
Species	A	B	C	D
Macoma inquinata	63.5 (1)	133.2 (1)	1.5	44.8 (1)
Melita dentata	48.3 (2)	1.4	23.0 (1)	3.7
Anisogammarus pugettensis	44.0 (3)	.3	0	2.5
Capitella capitata	31.0 (4)	5.8	.5	.8
Anaitides williamsi	30.5 (5)	.4	8.5 (4)	.7
Protothaca staminea	24.6 (6)	36.6 (7)	.5	14.3 (6)
Photis brevipes	22.2 (7)	30.1 (9)	1.0	13.5 (7)
Heptacarpus paludicola	16.2 (8)	.2	8.0 (5)	.5
Crangon nigricauda	12.0 (9)	5.0	20.5 (2)	.7
Platynereis bicanaliculata	9.9 (10)	1.3	2.0	3.5
Orchomenella sp. 1	.3	74.1 (2)	1.5	14.8 (5)
Olivella pycna	.7	71.0 (3)	.5	7.3 (8)
Paraphoxus epistomus	.2	61.6 (4)	10.5 (3)	30.3 (2)
Owenia collaris	1.4	42.7 (5)	.5	16.3 (3)
Olivella biplicata	.1	38.2 (6)	1.0	.2
Aglaja diomedea	.2	32.0 (8)	0	2.8
Glycinde picta	8.0	24.2 (10)	.5	7.0 (9)
Pontogeneia inermis	3.1	.4	4.0 (6)	0
Podocerus sp. 1	0	.1	4.0 (6)	0
Caprella laeviuscula	.1	1.4	4.0 (6)	.2
Paleanotus bellis	2.3	.2	3.5 (9)	.2
Arcnaeomysis grebnitzkii	0	2.5	3.5 (9)	.7
Cryptomya californica	6.1	22.6	1.0	16.3 (3)
Amphissa columbiana	.2	10.3	0	5.8 (10)

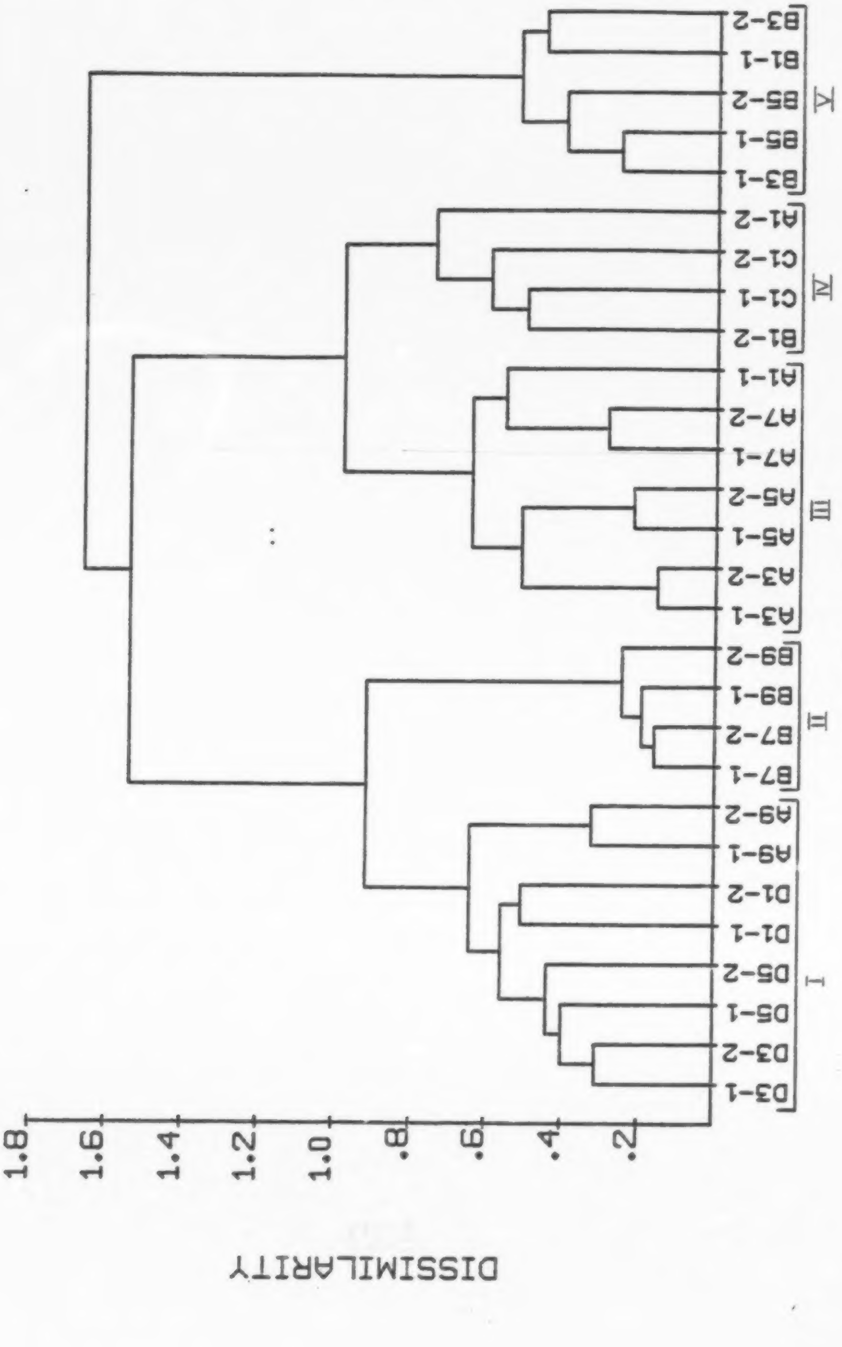
The dominant species were most similar at transects B and D (Table 7). The following eight species were among the ten most abundant at both of these transects: *Macoma inquinata*, *Protothaca staminea*, *Photis brevipes*, *Orchomenella* sp. 1, *Olivella pycna*, *Paraphoxus epistomus*, *Owenia collaris*, and *Glycinde picta*. *Cryptomya californica* and *Amphissa columbiana* ranked within the top ten at D, but not at B although the mean catch of both species per dredge sample was actually greater at B. The mean catch of all ten of the most abundant species at B was greater than at any other transect. The sixth and eighth most abundant species at B, *Olivella biplicata* and *Aglaja diomedea*, were relatively rare at the other transects.

The dominant fauna at transect C was not closely related to that of any other transect. The five least abundant dominants at C (*Pontogeneia inermis*, *Podocerus* sp. 1, *Caprella laeviuscula*, *Paleanotus bellis*, and *Archaeomysis grebnitzki*) did not rank within the top ten at any other transect and had rather low densities (≤ 4 individuals/dredge). Four of the five most abundant species at C were also dominants at A: *Melita dentata*, *Anaitides williamsi*, *Heptacarpus poludicola*, and *Crangon nigracauda*. *Paraphoxus epistomus* was a dominant at C, B, and D. Transect A shared the four dominant species listed above with C, and three species (*Macoma inquinata*, *Protothaca staminea*, and *Photis brevipes*) with both B and D. Two of the most abundant species at A (*Capitella capitata* and *Platynereis bicanaliculata*) were present, but not dominant at B, C, or D.

Numerical Classification

The pattern of overlap between transects in the composition of the dominant species suggests a lack of faunal homogeneity within the transects. The normal classification of the data set resulted in five reasonably well-defined collection groups (Fig. 6). Twelve of the 14 station replicate pairs

Fig. 6. Collection group clusters of Yaquina Bay benthic samples.


DISSIMILARITY
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
D3-1
D3-2
D5-1
D5-2
D1-1
D1-2
A9-1
A9-2
B7-1
B7-2
B9-1
B9-2
A3-1
A3-2
A5-1
A5-2
A7-1
A7-2
A1-1
B1-2
C1-1
C1-2
A1-2
B3-1
B5-1
B5-2
B1-1
B3-2
I
II
III
IV
V
COLLECTION GROUP

of samples fell within the same collection group and 11 of these were "nearest neighbors." That result lends credence to a quantitative analysis of dredge samples which are often considered qualitative at best.

Samples taken along individual transects did not always fall into the same collection group (Fig. 6). Group I includes all transect D samples plus the replicates taken at station A9. Group II includes all samples from stations B7 and B9 and possesses the lowest within group faunal dissimilarity. Group III is restricted to the A transect and includes sample A1-1 and both replicates at stations A3, A5 and A7. The two replicates at C1 and samples A1-2 and B1-2 are included in Group IV which has the highest within group dissimilarity. Group V inclues sample B1-1 and the replicates at stations B3 and B5. At higher hierarchical levels, Group I is most closely related to II, and III to IV. Group V is quite distinct from the other collection groups.

In contrast to the statistical comparison of community structure parameters between transects, there were highly significant differences in areal richness, density of individuals, dominance, and H' diversity between the five collection groups (Table 8). Student-Newman-Keule multiple range test at the 0.05 probability level showed that mean areal richness of Group V (21.0 species) was not different from Group IV (23.2), but both means were less than in the other groups. Richness at III (34.1 species) and I (37.6) were not different. Richness at II (47.2 species) was greater than at III, but the difference between II and I was barely insignificant. The mean density of individuals was greater at II (1245.0 individuals) and less at IV (83.0) than at any other groups. Density at I (347.8 individuals), III (367.4), and V (417.4) were not different from one another. Mean values for the complement of Simpson's Index of dominance and H' diversity were very low at Group V (0.73 and 0.76, respectively) and significantly different from all

Table 8. Mean richness, density, dominance, and diversity of benthic samples in Yaquina Bay Collection Groups.

Parameter		Collection Group					Analysis of Variance
		I	II	III	IV	V	
Areal Richness (S/Dredge)	$\bar{x}$	37.6	47.2	34.1	23.2	21.0	F = 7.59**
	Range	29-50	41-53	22-43	10-40	11-35	
Density of Individuals (N/Dredge)	$\bar{x}$	347.8	1245.0	367.4	83.0	417.4	F = 25.95**
	Range	104-842	1180-1283	80-647	30-181	272-549	
Dominance (1-Simpson's Index)	$\bar{x}$	0.86	0.88	0.87	0.90	0.73	F = 4.76**
	Range	0.74-0.93	0.84-0.90	0.81-0.91	0.87-0.93	0.54-0.86	
Diversity (h')	$\bar{x}$	1.13	1.12	1.09	1.12	0.76	F = 5.50**
	Range	0.84-1.37	1.02-1.18	0.94-1.19	0.90-1.28	0.49-1.04	

*$F_{0.05(23,4)} = 2.80$; **$F_{0.01(23,4)} = 4.26$

other groups. Within the other groups there were no differences in either dominance or H" diversity which varied between 0.86 - 0.90 and 1.09 - 1.13, respectively.

The inverse classification resulted in five species groups (Fig. 7, Table 9). Two way analyses of the mean number of individuals/sample and constancy of species groups in collection groups are shown in Tables 10 and 11, respectively.

One of the major results of the numerical classification was a division of all except one of the B transect samples into collection groups (CG) II and CG V which were distinctly different from one another. Group V included both replicates from stations B3 and B5 plus sample B1-1. It was strongly dominated by *Olivella pycna*, *O. biplicata* and *Paraphoxus epistomus*. These three species had a total mean abundance of 334.8 individuals/sample and accounted for 80% of the individuals collected in CG V. Their dominance accounts for the very low mean values for H' diversity (0.76) and the complement of Simpson's Index (0.73). None of the other species collected in these samples were very abundant. The high constancy and abundance of species group (SG) 5 in CG V merely reflects the ubiquity and density of the three dominants. The other ten species in SG 5 had only a moderate constancy (0.36) and low mean density (2.1 individuals/species/sample). *Glycinde picta* was the only species other than the dominants that appeared in all five samples. CG V had the lowest areal richness ($\bar{x}$ S/sample = 21.0) and, excluding the three dominants, the lowest mean density (82.6 individuals/sample) of any collection group.

The replicates from stations B7 and B9 constituted collection Group II which had the highest density of individuals, areal species richness, and within group faunal homogeneity of any of the collection groups. Species

Fig. 7. Species group clusters for Yaquina Bay samples.

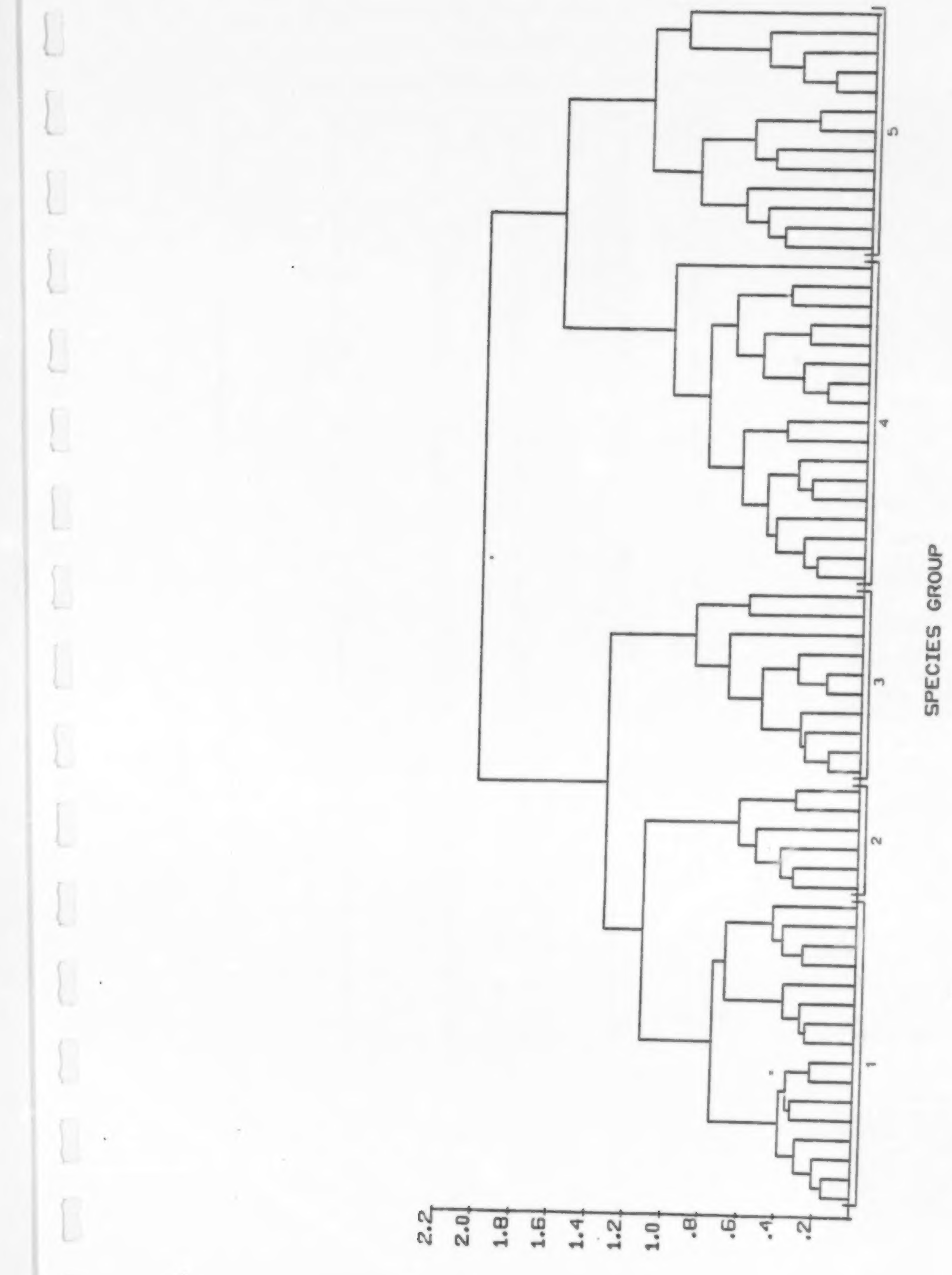

DISSIMILARITY
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
1
2
3
4
5
SPECIES GROUP

Table 9. Mean density of individuals in dredge samples within each collection group for members of each species group. Rank of the ten most abundant species within each collection group is given in parentheses.

	Collection Group				
	I	II	III	IV	V
Species Group 1					
Glycinde picta	12.8 (7)	56.0 (8)	2.7	.5	3.6
Macoma inquinata	96.2 (1)	331.5 (1)	19.2 (6)	.8	1.2
Protothaca staminea	36.6 (2)	89.2 (4)	5.6	.2	1.8
Haploscoloplos elongatus	6.4	11.0	.4	0	.2
Sphaerosyllis californiensis	1.5	7.8	2.0	0	0
Diastylis alaskensis	4.4	8.8	1.3	.2	1.0
Photis brevipes	12.5 (8)	74.8 (6)	28.7 (4)	1.2	.2
Cryptomya californica	13.9 (6)	56.5 (7)	6.3	1.5	0
Mediomastus californiensis	4.5	11.5	.4	0	2.2
Owenia collaris	14.0 (5)	90.5 (3)	0	.2	13.0 (4)
Protomedeia zotea	1.8	12.5	0	0	.2
Prionospio malmgreni	1.5	1.2	0	0	.8
Odostomia phanea	2.2	20.5	.6	0	2.4
Lamprops quadriplicata	2.8	30.8 (9)	0	.2	3.8 (9)
Tellina modesta	3.1	10.0	0	0	8.2 (5)
Amphissa columbiana	4.4	17.2	.3	0	6.8 (7)
Species Group 2					
Mytilus edulis	5.0	2.2	1.0	.5	0
Cancer magister	6.5 (10)	1.2	1.6	1.8	1.4
Pinnixia schmitti	6.4	1.0	.3	0	0
Gemma gemma	3.8	.5	.9	0	0
Cirratulus cirratus	6.2	.5	.7	0	0
Eupolymnia crescentis	1.8	0	0	.5	0
Species Group 3					
Tharyx parvus	0	30.5 (10)	0	0	0
Mitrella tuberosa	0	27.5	0	0	0
Ampharete arctica	0	3.2	.4	0	0
Dendraster excentricus	.1	3.0	0	0	.2
Aglaja diomedea	2.2	80.0 (5)	.1	0	0
Orchomenella sp. 1	11.2 (9)	164.8 (2)	.3	.8	.4
Nassarius mendicus	.5	27.2	0	0	.2
Nephtys caecoides	.6	1.2	0	0	0
Rhyncospio arenicola	.2	1.8	.3	0	0
Epitonium indianorum	0	4.5	0	0	0
Species Group 4					
Crangon nigricauda	1.1	1.8	16.1 (8)	12.5 (2)	7.2 (6)
Pontogeneia inermis	.1	0	4.1	2.5 (7)	.6
Melita dentata	3.6	1.0	67.6 (1)	13.0 (1)	1.4
Gnorimosphaeroma oregonensis	.1	0	1.4	.2	0
Cancer productus	.4	0	7.4	.2	.2
Cancer oregonensis	.2	0	3.3	.2	0
Paleanotus bellis	.4	.2	3.0	2.0	0
Heptacarpus paludicola	.6	0	22.3 (5)	5.2 (4)	.2
Pholis ornata	.1	0	2.3	0	0
Anaitides williamsi	.9	0	42.7 (3)	5.0 (5)	.8
Lumbrineris zonata	.5	0	7.9 (10)	.2	0
Anisogammarus pugettensis	3.6	.8	59.6 (2)	2.2 (9)	0
Harmothoe imbricata	1.1	1.5	6.1	.2	0
Platynereis bicanaliculata	3.9	2.8	12.7 (9)	1.0	.4
Armandia brevis	1.1	0	.7	0	.4
Capitalla capitata	24.4 (3)	14.2	17.1 (7)	.2	.2
Petrolisthes eriomerus	0	.2	6.0	0	0
Species Group 5					
Clinocardium nuttalli	1.0	1.0	.1	.8	.4
Parapleustes pugettensis	.9	.2	0	2.2 (9)	.6
Paraphoxus spinosus	2.1	.2	.9	2.5 (7)	1.6
Caprella laeviuscula	.1	0	.1	3.8 (6)	1.4
Archaeomysis grebnitzkii	.5	0	0	1.8	5.0 (8)
Mandibulophoxus gilesi	0	0	0	0	2.2
Hippomedon denticula	0	0	0	.5	2.0
Eohaustorius estuarius	.2	0	0	0	3.8 (9)
Olivella pycna	5.5	5.5	1.0	.5	137.4 (1)
Olivella biplicata	.1	.5	.1	1.0	75.6 (3)
Paraphoxus epistomus	22.8 (4)	1.0	.3	6.0 (3)	121.8 (2)
Parophrys vetulus	0	1.2	.6	0	3.6
Caprella californica	.1	0	1.4	.8	.2

Table 10. Mean density of species groups in dredge samples within Yaquina Bay collection groups.

	Species Group				
Collection Group	1	2	3	4	5
I	218.5	29.6	15.0	42.2	33.4
II	829.8	5.5	363.8	22.5	9.8
III	67.4	4.4	1.1	280.4	4.6
IV	5.0	2.8	0.8	45.0	19.8
V	45.4	1.4	0.8	11.4	355.6

Table 11. Constancy of species groups within Yaquina Bay collection groups. Very high values (>.75) are underlined twice, high values (.50-.74), once.

Collection Group	Species Group 1	2	3	4	5
I	.78	.77	.24	.43	.28
II	.97	.62	.85	.26	.31
III	.44	.43	.09	.80	.19
IV	.20	.29	.03	.41	.38
V	.40	.13	.06	.18	.51

Groups 1 and 3 are dominant (Tables 9, 10). Constancy was high or very high for both of these species groups plus SG 2, although the latter was represented by very few individuals (Table 11). SG 3 was almost entirely restricted to CG II. SG 1 reached its maximum abundance in CG II, but it was also the dominant species group in CG I.

Macoma inquinata and *Orchomenella* sp. 1 were the first and second most abundant species in each of the four CG II samples. The tremendous faunal homogeneity of this group was also due to the ubiquitous presence of 25 species in all samples. The other dominants include *Owenia collaris*, *Protothaca staminea*, *Aglaja diomedea*, *Photis brevipes*, *Cryptomya californica*, *Glycinde picta*, *Lamprops quadriplicata*, and *Tharyx parvus*. All of these species reached their maximum abundance in this collection group.

The benthos at B7 and B9 was very different from that at the other B transect stations, especially CG V. Only two species, *Owenia collaris* and *Glycinde picta*, ranked within the ten most abundant species in both CG II and CG V. The three dominants at CG V, *Olivella pycna*, *O. biplicata* and *Paraphoxus epistomus* had a total mean abundance per dredge sample of only 7.0 individuals within CG II.

Numerical classification also subdivided the A transect stations. The replicates at A9 clustered with all D transect samples in collection Group I. The remainder of the A samples (except for A1-2) formed collection Group III. The structure of the benthos in these groups is very similar, but the dominant species are rather different (Table 9). Only three species (*Macoma inquinata*, *Capitella capitata*, and *Photis brevipes*) appear within the ten most abundant species in both collection groups. The dominants in CG III (*Melita dentata*, *Anisogammarus pugettensis*, and *Anaitides williamsi*) were not abundant in CG I. CG I was much more closely related to CG II (stations B7, 9) in dominant species composition. Species groups 1 and 2 were abundant and had very high constancy within CG I (Tables 10, 11). Species group 4 was most abundant and ubiquitous in CG III.

The distribution of the opportunistic polychaete Capitella capitata is shown in Table 12. Although C. capitata ranks as the third most abundant species in CG I, it was present in only three (D3-1, A9-1, A9-2) of the eight CG I samples. Its spatial distribution indicates a gradient of increasing density along both the A and B transects. It reached its maximum abundance at stations A7, A9, and B9. These collections contained a great variety of other species and relatively high faunal densities.

The two replicates taken on the C transect and samples A1-2 and B1-2 form collection Group IV. These samples contained relatively few species and individuals. The lack of any real dominant species resulted in relatively high values of H' diversity and the complement of Simpson's Index (Table 8). The constancy and abundance of all species groups was low in CG IV (Table 10, 11). Melita dentata was the most abundant species, but its mean density/sample was only 13.0 individuals. The composition of the "dominant" species in CG IV most closely resembles that of CG III.

Unidentified Species

The preceding results are based on those individuals which were identified to the species level. Specimens which could be identified only at higher taxonomic levels are listed in Table 13 for both transects and collection groups. The highest density of unidentified individuals was found at the A transect and in collection Group III which includes 7 of the 10 A transect samples. A relatively high abundance of anomuran megalopae is evident in CG III and of ophiuroideans in CG II (stations B7 and B9).

Table 12. Distribution of Capitella capitata in Yaquina Bay samples.

	Number of Individuals									
	Dredge Sample									
Transect	1-1	1-2	3-1	3-2	5-1	5-2	7-1	7-2	9-1	9-2
A	2	0	19	8	7	15	46	23	25	165
B	1	0	0	0	0	0	5	3	41	8
C	1	0								
D	0	0	5	0	0	0				

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Table 13. Distribution of taxa not identified to the species level in Yaquina Bay transects and collection groups.

	Transect				Collection Group				
Taxon	A	B	C	D	I	II	III	IV	V
Anomuran megalopae	10.7	.1	0	1.3	1.9	.2	10.4	.8	0
Pycnogonida	3.2	5.2	8.5	2.5	2.1	1.2	4.3	6.2	7.8
Ophiuroidea	1.4	7.7	.5	0	0	18.5	2.0	.2	.6
Nudibranchia	4.8	1.7	2.0	.3	.2	0	6.7	1.2	3.4
Brachyuran megalopae	3.2	.5	3.0	3.8	3.0	.5	4.3	1.8	.6
Nemertea	2.5	.3	0	1.0	1.5	.8	2.7	0	0
Polycladida	.1	.1	5.5	0	0	0	.1	2.8	.2
Anthozoa	.3	0	.5	0	0	0	.3	.2	.2
TOTAL	26.2	15.6	20.0	8.9	8.7	21.2	30.8	13.2	12.8

DISCUSSION AND CONCLUSIONS

Cannery Effluents

The effects of seafood cannery effluents on water and sediment quality in Yaquina Bay are restricted to the immediate vicinity of the cannery docks. The effluent plume is quite turbid and has high nutrient concentrations. Because of its initial low salinity it is restricted to the surface layer where it mixes rapidly with estuarine water and is dispersed by strong tidal currents. The quality of water at the bottom along the A transect was comparable to that at other stations in the Bay. The dissolved oxygen concentration at both the surface and bottom was not less than 7 mg/l.

The strength of the currents along cannery row and the screening treatment of the effluents minimize the deposition of waste materials on the sea bed. There was no evidence for a major increase in the concentration of any chemical parameter in the sediments along the A transect. However, concentrations of Kjeldahl nitrogen, total and hydrocarbon oil and grease, and total and alkaline soluble sulfides were generally higher than at the other transects although the ranges often overlapped. Television observations and the dredged samples did not indicate the accumulation of shells or other waste products on the bottom. There was, however, a greatly increased incidence of human artifacts on the bottom at the A stations.

A very diverse and abundant macrofaunal benthic community was found immediately adjacent to the cannery outfalls (transect A). Although this assemblage differed in species composition from the benthos collected across the Bay at the Oregon State University docks (transect D), there were no statistical differences in community structure parameters of density, dominance, diversity or richness.

Tidal or current dispersion of wastes seems to be the major factor determining the impact of cannery effluents. Beyer, Nakatani and Staude (1975) examined environmental conditions near salmon cannery outfalls in an area of strong tidal action at Petersburg, Alaska. Their results are similar to ours. DO concentrations near the Petersburg canneries were not lower than ambient values. Turbidity was high only in the immediate vicinity of the outfalls. Their analysis of intertidal communities indicated that spatial differences could not be attributed to outfall effects. The Petersburg effluents were not screened, resulting in temporary accumulations of heads, tails and viscera in a small area north of the outfalls. The subtidal benthos was less diverse beneath these accumulations. Beyer et al. (1975) believed that grinding wastes would alleviate this problem.

Cannery effluents can cause major environmental degradation if flushing is inadequate. Stewart and Tangarone (1977) and Karna (1978) examined water and sediment quality in the vicinity of seafood cannery outfalls in Dutch Harbor, Alaska. They found that DO concentrations in bottom water were often less than 6 mg/l and in one instance the bottom water was anaerobic. Concentrations of ammonia and total phosphorus at the bottom were substantially greater than at control locations. Most of the shells and heavier wastes accumulated on the bottom within a 30 m radius of the outfalls. Deposits of less dense material extended well beyond the 30 m radius. These deposits resulted in high concentrations of hydrogen sulfides and organic matter in the sediments. Qualitative observations during diving surveys indicated a greatly reduced richness of benthic species in the area of waste deposits.

Reish (1959) and Barnard and Reish (1959) reported a tremendous degradation of the macrobenthos in poorly flushed embayments next to fish canneries in Los Angeles Harbor and Newport Bay, California. Only 7 species and 134 individuals were collected from the cannery area in Newport Bay, and 3 species and 88 individuals in Los Angeles Harbor. The widely recognized pollution indicator species, Capitella capitata, accounted for about 90% of the individuals in both cases. This polychaete reached its maximum density in our survey at stations A7, A9, and B9. The collections at these stations contained an average of 45 species and 715 individuals per dredge sample. _C. capitata_ accounted for about 7% of the individuals. We do not believe that a significant ecological alteration is indicated by the presence of an opportunistic species in the midst of such an abundance and variety of other benthic invertebrates.

This report concerns cannery effluent impacts on the macrobenthos, sediment and water quality as determined from a single ecological survey. Limitations in time and resources prevented an analysis of temporal changes or effects on other biological communities. One assemblage that certainly warrants additional study is the intertidal fauna and flora on the pilings and rocks beneath the cannery docks. Michael Mix (personal communication) has observed a high incidence of mortality, abnormal and possibly neoplastic cells, and inhibited gametogenesis in mussels, _Mytilus edulis_, collected from the cannery dock pilings in Yaquina Bay. These disorders were correlated with increased body burdens of benzo(α)pyrene, a carcinogenic petroleum hydrocarbon. The source of the benzo(α)pyrene is uncertain. Dunn and Stich (1976) attributed elevated levels of benzo(α)pyrene in mussels growing near pilings in Vancouver harbor to the creosote used as a piling preservative.

Spatial Heterogeneity in Yaquina Bay Benthos

We observed substantial within and between transect variations in the structure and species composition of Yaquina Bay benthic assemblages. The characteristics of the benthos on the A transect do not seem to be attributable to cannery outfall effects. There were no substantial differences between any of the stations in the temperature, salinity or dissolved oxygen in water near the bottom. Water depth was slightly greater at the channel stations (A1, B1, C1), but major differences in the benthos were found between stations of comparable depth. Sediment particle size distribution is the only environmental factor that was closely related to spatial changes in the benthos.

The numerical classification of the Yaquina Bay samples produced five collection groups. The stations which clustered together on the basis of faunal similarity are also similar in sediment characteristics. In Table 14 the sediment preferences as described in the scientific literature are given for benthic species collected in Yaquina Bay. Species are listed in Table 14 within the collection group in which they achieved their maximum abundance (see Table 9 for density data).

Most of the species reached maximum density in collection groups II or III. Sediments at these two groups of collections were distinctly different. CG II includes stations B7 and B9 which were the only stations in which the sediment contained a large proportion of fine particles. Almost all species which were most abundant at CG II are described in the literature as having a preference for muddy sand or similar fine sediment types (Table 14). All species which reached their maximum abundance in CG II were clustered in species groups 1 and 3 by the inverse numerical classification. The distinction between these two species groups is that the members of SG 3 have a stronger preference for muds and were almost entirely restricted to CG II (Tables 14, 9). SG 1 however was more tolerant of sandier sediments and therefore had a wider spatial distribution in the Bay.

In contrast to the muddy sediments at CG II, the sediments at CG III (sample A1-1 and both replicates at A3, 5, 7) were poorly sorted and contained a large proportion of coarse sands, gravel and shells. The literature indicates that the species with a maximum density at CG III had a preference for coarse sediment types (Table 14). These species were restricted to SG 4 which was also present, but much less abundant in CG IV

Table 14. Sediment preference of Yaquina Bay macrobenthos as described in the scientific literature. Species are assigned to the collection group in which they achieved their maximum density.

Collection Group Stations Sediment Type	Species	Species Group	Sediment Preference	Reference
Collection Group II Stations B7, B9 Fine sand, silt and clay.	*Glycinde picta*	1	sandy mud	1,2
	Macoma inquinata	1	silt and mud	1
	Protothaca staminea	1	sandy mud, sands, gravel, rocks	1,3,4
	Haploscoloplos elongatus	1	very fine sands, muddy sand	5,6,7
	Sphaerosyllis californiensis	1	silt, mud, and mixed sediment	1,7
	Cryptomya californica	1	mud or sand	1
	Mediomastus californiensis	1	mud, fine or very fine sand	1,2,6,8
	Owenia collaris	1	muddy sand, fine sand	1,9,10,11
	Lamprops quadriplicata	1	fine sand	12
	Tellina modesta	1	silty sand, sand	1,13
	Amphissa columbiana	1	sand, gravel, rocks	1
	Tharyx parvus	3	fine silty muds, muddy sands	1,8,14
	Mitrella tuberosa	3	sand and gravel	1
	Ampharete arctica	3	mud	15
	Aglaja diomedea	3	mudflats	1,3,16
	Nassarius mendicus	3	mud, sand, rocks	1
	Rhyncospio arenicola	3	muddy sand	17
	Orchomenella sp.	3	sandy mud	18
Collection Group III Stations A1,3,5,7 Poorly sorted sands, gravel and shell.	*Crangon nigricauda*	4	rocks, sand	1
	Melita dentata	4	rocks, stones	19
	Gnorimosphaeroma oregonensis	4	sand, stones, gravel, rocks	20
	Anisogammarus pugettensis	4	marshes	1
	Cancer productus	4	coarse sands, gravel, rocks	21
	Heptacarpus paludicola	4	pools on mudflats and rocky intertidal	1
	Anaitides williamsi	4	muddy sand, shell fragments	1,14
	Lumbrineris zonata	4	mixed sediments or clean sand	7
	Harmothoe imbricata	4	rocks	1
	Platynereis bicanaliculata	4	sand, shells, rocks	1,14
	Petrolisthes eriomerus	4	rocks	22,23
Collection Group V Stations B1,3,5 Very well sorted fine sands	*Eohaustorius estuarius*	5	clean, medium sand	24
	Paraphoxus epistomus	5	medium fine unstable sand	19,25
	Olivella biplicata	5	clean sand	1
Collection Group I Stations A9, D1,3,5 Fine and medium sands	*Cancer magister*	2	sand	1,21
	Gemma gemma	2	sands or muddy sands	26
	Cirratulus cirratus	2	sand, rocks	1,27
	Eupolymnia crescentis	2	sandy mud	1
	Capitella capitata	1	organically enriched fine sediments	1,14,28

1 Smith and Carlton (1975), 2 Barnes (1966), 3 Ricketts and Calvin (1952), 4 Fitch (1953), 5 Reish (1963), 6 Reish (1964), 7 Hartman (1968), 8 Vassallo(1970), 9 Perkins (1974), 10 Hartman (1969), 11 Fager (1964), 12 Given (1965), 13 Maurer (1967), 14 Barnard and Reish (1959), 15 Sanders (1960), 16 Abbott (1974), 17 Wieser (1959), 18 Hurley (1963), 19 Bousfield (1973), 20 Rees (1975), 21 Schmitt (1921), 22 Gonor and Gonor (1973), 23 Knudsen (1964), 24 Bosworth (1973), 25 Maurer *et al*. (1974), 26 Narchi (1971), 27 Reish (1949), 28 Warren (1977).

(samples A1-2, B1-2, C1-1 and 2). The sediments at CG IV were shells and gravel [sediment data given in Table 2 are representative of the first replicate taken at stations A1 and B1]. The depauperate fauna in CG IV may be related to the location of these stations in channels where they are subjected to dredging and a great deal of ship activity.

Very well sorted fine sands occurred in sample B1-1 and both replicates at stations B3 and B5 (CG V). Species group 5 was dominant and its members are known to prefer clean fine or medium sands (Table 14). Medium and fine sands are present at CG V (the D transect and station A9). Species group 2 reached its maximum abundance at CG V and with the exception of *Mytilus edulis*, it is a sand dwelling assemblage.

In summary, sediment composition is a major factor controlling the distribution of subtidal benthic invertebrates in Yaquina Bay. Two major assemblages were encountered in our survey. The muddy sands at stations B7 and 9 support a very abundant and diverse benthic community dominated by *Macoma inquinata*, *Orchomenella* sp. 1, and *Owenia collaris*. The more psammophilic species in this community were also abundant in the medium and fine sands at station A9 and the D transect. The second major assemblage was found in the coarser sediments along most of the A transect. The more abundant species there were *Melita dentata*, *Anisogammarus pugettensis*, and *Anaitides williamsi*. A depauperate example of this community was encountered in coarse channel sediments. The fine clean sands along channel banks were densely populated by only three species, *Olivella pycna*, *O. biplicata*, and *Paraphoxus epistomus*.

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Appendix 1. Raw data set for the macrofaunal benthic collections made in Yaquina Bay, Oregon on 9-10 May 1978.

	A1-1	A1-2	A3-1	A3-2	A5-1	A5-2	A7-1	A7-2	A9-1	A9-2
ACMAEA SP	1									
ACTEOCINA CULCITELLA									1	
AGLAJA DIOMEDEA			1						1	
AMAENA OCCIDENTALIS	1									
AMPHARETE ARCTICA								3		
AMPHISSA COLUMBIANA	1					1				
AMPITHOE LACERTOSA				1						
ANAITIDES WILLIAMSI	6	3	74	93	4	27	35	60	1	2
ANISOGAMMARUS CONFERVICOLUS					2					
ANISOGAMMARUS PUGETTENSIS	6	[illegible]	162	232		2	7	8	2	12
ANOMURAN MEGALOPA	3	1	26	19	17	5	18	9	1	6
ANTHOZOAN UNID		1						2		
ARMANDIA BREVIS			2			1	2		1	7
BARNEA SUBTRUNCATA				1						
CANCER MAGISTER	2		3	3	1	1		1	5	14
CANCER OREGONENSIS			6	1	3	2	6	3		1
CANCER PRODUCTUS	4		14	11	8	7	4	4		3
CAPITELLA CAPITATA	2		19	8	7	15	46	23	25	165
CAPRELLA CALIFORNICA					1		9			
CAPRELLA LAEVIUSCULA					1					
CIRRATULUS CIRRATUS					1	3		1	8	8
CISTENIDES BREVICOMA						1			1	
CLINOCARDIUM NUTTALLI			1						1	2
COROPHIUM OAKLANDENSE			3							
CRAB MEGALOPA	1	1	10	6		7	1	5	1	
CRANGON NIGRICAUDA		2	11	12	29	58		3		5
CRYPTOMYA CALIFORNICA	2	4	6	5	3	7	12	9	6	7
DIASTYLIS ALASKENSIS			2	3		1	3		6	9
DYNAMENELLA SHEARERI			2			1				
ENOPHRYS BISON			1		1			1		
EOHAUSTORIUS ESTUARIUS										1
EULALIA AVICULISETA				2			1			
EUPOLYMNIA CRESCENTIS									1	2
EUSYLLIS BLOMSTRANDI			2			2				
GEMMA GEMMA			5	4					5	9
GLYCINDE PICTA		1	2	1	1	2	6	7	12	48
GNORIMOSPHAEROMA OREGONENSIS	1		4	1	3	1				
GYPTIS BREVIPALPA										1
HAPLOSCOLOPLOS ELONGATUS						3			7	20
HARMOTHOE IMBRICATA			12	6	4	15	3	1	2	
HEPTACARPUS PALUDICOLA	1	4	4	1	71	77	1	1	1	1
HETEROMASTUS FILOBRANCHUS							1			1
HIATELLA ARCTICA					1					
IDOTEA FEWKESI				1		2	1			
ISOPOD A				1						
JASSA FALCATA									2	
LACUNA MARMORATA						1	1			
LAMPROPS QUADRIPLICATA									7	1
LATOCHELIA DUBIA										2
LIMNORIA LIGNORUM								1		
LUMBRINERIS ZONATA	1		30	19	1	1	5	9		2
MACOMA INQUINATA	11		23	14	21	24	29	15	172	329
MACOMA NASUTA							1			
MEDIOMASTUS CALIFORNIENSIS								1	3	5
MELITA DENTATA	27	3	121	112	83	106	4	6	1	8
MICROPODARKE DUBIA			2	2		2				2
MIMULUS FOLIATUS			1							
MYTILUS EDULIS				1	1	1	2	2		9
NEMERTEAN UNID					12	3		4	1	5
NEPHTYS CAECOIDES										1
NEPHTYS FERRUGINEA										2
NUDIBRANCH UNID	1	1	15	14	3	5	5	4		
ODONTOSYLLIS PARVA							1			
ODOSTOMIA SP					1	4				
ODOSTOMIA PHANEA	1				1	2			2	3
OLIVELLA BIPLICATA			1							
OLIVELLA PYCNA	1		3		2			1		
OPHIUROIDEA UNID			1	1	2	7	2	1		
ORCHOMENELLA SP 1				1			1			1
OWENIA COLLARIS									1	13
PAGURUS SAMUELIS	1									2
PALEANOTUS BELLIS			10		3	4	1	3		2
PARAPHOXUS EPISTOMUS					1	1				
PARAPHOXUS SPINOSUS			4	1				1		
PARAPLEUSTES PUGETTENSIS										2
PAROPHRYS VETULUS			1	1	2					
PEISIDICE ASPERA					1					
PETROLISTHES ERIOMERUS			29	13						
PHOLIS ORNATA			4		7	4	1		1	
PHOTIS BREVIPES	2	2	53	61	28	26	21	10	8	11
PINNIXIA SCHMITTI			1	1					6	10
PIONOSYLLIS GIGANTEA						1				
PISASTER BREVISPINUS										1
PLATYNEREIS BICANALICULATA	1		12	13		19	36	9	1	9
POLYCLADIDA UNID				1						
POLYNOID SP A			2							
POLYNOID SP B			1	1						
PONTOGENEIA INERMIS		1	5	5	12	6		1		1
PRIONOSPIO CIRRIFERA			1							2
PRIONOSPIO MALMGRENI									1	1
PROTOTHACA STAMINEA	6		12	2	2	3	5	9	117	90
PSEUDOPOTAMILLA SOCIALIS								2		
PUGETTIA PRODUCTA							2			
PYCNOGONID UNID	1		4	12	3	4	6		1	1
PYCNOPODIA HELIANTHOIDES	1	1					1			
RHOMBOIDELLA COLUMBIANA								1		
RHYNCOSPIO ARENICOLA							1	1	1	
SAXIDOMUS GIGANTIUS				1						1
SCYRA ACUTIFRONS						1				
SPHAEROSYLLIS CALIFORNIENIS			3	2		4	5			9
SPIOPHANES FIMBRIATA										1
SYLLIS SP (BANSE)				1			2	2		3
TELLINA MODESTA										2
TIRON BIOCELLATA					1		1			
TRANSENNELLA TANTILLA										1
TRITELLA LAEVIS	1									
VENERUPIS PHILIPPINARUM			1							

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	B1-1	B1-2	B3-1	B3-2	B5-1	B5-2	B7-1	B7-2	B9-1	B9-2
ACTEOCINA CULCITELLA								1		
ACTEOCINA HARPA							2	1	2	1
AGLAJA DIOMEDEA							79	75	34	128
AMPHARETE ARCTICA							5	2	6	
AMPHISSA COLUMBIANA					6	28		2	23	44
ANAITIDES WILLIAMSI	2									
ANISOGAMMARUS PUGETTENSIS								3		
ANOMURAN MEGALOPA										1
ARCHAEOMYSIS GREBNITZKII	25									
ARMANDIA BREVIS	1					1				
CALIANASSA CALIFORNIENSIS										1
CANCER MAGISTER	3	1	1	1		2	1	1	1	1
CANCER OREGONENSIS		1								
CANCER PRODUCTUS						1				
CAPITELLA CAPITATA	1						5	3	41	8
CAPRELLA CALIFORNICA						1				
CAPRELLA LAEVIUSCULA	7	7								
CIRRATULUS CIRRATUS								1	1	
CISTENIDES BREVICOMA								1	1	1
CITHARICHTHYS SORDIDUS						1				
CLINOCARDIUM NUTTALLI	1			1			2		1	1
COROPHIUM OAKLANDENSE										1
CRAB MEGALOPA	2				1			1		
CRANGON NIGRICAUDA	27	7	1		5	3	5	1	1	
CRYPTOMYA CALIFORNICA							50	18	90	65
CUMELLA VULGARIS									1	
DENDRASTER EXCENTRICUS	1						3	4	5	
DIASTYLIS ALASKENSIS						5	11	13	2	0
ENOPHRYS BISON		1								
EOHAUSTORIUS ESTUARIUS	14		2	3						
EPITONIUM INDIANORUM									5	10
EUSYLLIS BLOMSTRANDI	1									
GEMMA GEMMA							1			1
GLYCINDE PICTA	1		1	1	6	9	56	70	58	40
HALOSYDNA BREVITOSA	1									
HAPLOSCOLOPLOS ELONGATUS					1		18	9	11	6
HARMOTHOE IMBRICATA							4		2	
HEPTACARPUS BREVIROSTRIS	1	1								
HEPTACARPUS PALUDICOLA	1	1								
HETEROMASTUS FILOBRANCHUS					1			1	3	1
HIATELLA STRIATA								1	1	
HIPPOMEDON DENTICULATUS	8	1	1	1						
IDOTEA FEWKESI								1		
LACUNA MARMORATA			1							
LAMPROPS QUADRIPLICATA			2		5	12	60	15	7	41
LETOCHELIA DUBIA								3		
LITTORINA SCUTULATA										1
LOXORHYNCHUS CRISPATUS									1	
LUMBRINERIS CALIFORNIENSIS								1		
LUMBRINERIS CRUZENSIS									1	
LYONSIA CALIFORNICA									1	
MACOMA INQUINATA					3	3	356	401	318	251
MANDIBULOPHOXUS GILESI	11									
MEDIOMASTUS CALIFORNIENSIS					10	1	6	7	16	17
MELITA DENTATA	4	3			1	2	1	1	1	1
MITRELLA TUBEROSA							46	17	45	2
MONOCULODES SPINIPES	3					1				
MYRIOCHELE HEERI								1	3	2
MYTILUS EDULIS							2	1	3	3
NASSARIUS MENDICUS					1		30	5	29	45
NEMERTEAN UNID								1	2	
NEPHTYS CAECA										1
NEPHTYS CAECOIDES							2	2		1
NEPHTYS CILIATA	4		1	1						
NEPHTYS FERRUGINEA								1		
NUDIBRANCH UNID	13		2		1	1				
ODOSTOMIA PHANEA						12	26	15	8	33
OLIVELLA BIPLICATA	68	2	133	25	105	47		1	1	
OLIVELLA PYCNA	88	1	202	55	207	135	2	3	5	12
OPHIUROIDEA UNID	1				1	1	20	13	22	19
ORCHOMENELLA SP I						2	160	243	151	185
OWENIA COLLARIS			4	1	41	19	81	75	112	94
PAGURUS SAMUELIS		1								
PALEANOTUS BELLIS		1							1	
PANDORA GLACIALIS									1	
PARAPHOXUS EPISTOMUS	98	3	146	179	138	48				4
PARAPHOXUS SPINOSUS	8	4								1
PARAPLEUSTES PUGETTENSIS	3	4					1			
PAROPHRYS VETULUS	7		1		7	3	1	1	1	2
PETROLISTHES ERIOMERUS							1			
PHOLOE TUBERCULATA								1		
PHOTIS BREVIPES	1	1					111	99	50	50
PINNIXIA SCHMITTI							1	2		1
PLATYNEREIS BICANALICULATA						2	8		3	
PODOCERUS SP I	1									
POLYCIRRUS SPI						1				
POLYCLADIDA UNID						1				
PONTOGENEIA INERMIS	3	1								
PRIONOSPIO CIRRIFERA							1		1	
PRIONOSPIO MALMGRENI			2		2		1	2	2	
PROTOMEDEIA ZOTEA					1		3	5	7	35
PROTOTHACA STAMINEA	1		1			7	63	128	140	26
PSEUDOPOTAMILLA SOCIALIS	1									
PYCNOGONID UNID	37	[illegible]	1		1		1	1	2	1
PYCNOPODIA HELIANTHOIDES	1									
RHYNCOSPIO ARENICOLA							1		1	5
SABELLARIA CEMENTARIUM	1									
SAXIDOMUS GIGANTEUS						1			1	1
SILIQUA PATULA									1	
SPHAEROSYLLIS CALIFORNIENSIS							5	10	8	9
SPIONIDAE SP 6								1		
SPIOPHANES BOMBYX								[illegible]		1
SPIOPHANES FIMBRIATA								[illegible]		1
SPIOPHANES SP A							1			
SYLLIS ELONGATA		2								
TELLINA BODEGENSIS									1	2
TELLINA MODESTA	5			11	9	16	9	[illegible]	9	16
TELLINA NUCULOIDES	1									
THARYX PARVUS							15	30	58	19
TRANSENNELLA TANTILLA									2	

	C1-1	C1-2	D1-1	D1-2	D3-1	D3-2	D5-1	D5-2
ACTEOCINA HARPA	1				1			
AGLAJA DIOMEDEA			5	7	1	4		
AMAENA OCCIDENTALIS					1	1		1
AMPHISSA COLUMBIANA			1	25	2	7		
AMPITHOE LACERTOSA						1		
ANAITIDES SP A				1			2	
ANAITIDES WILLIAMSI	17			1	1		1	1
ANISOGAMMARUS PUGETTENSIS			1	2	2	7	1	2
ANOMURAN MEGALOPA			3		3	2		1
ANTHOZOAN UNID	1							
ARCHAEOMYSIS GREBNITZKII	7		3				1	
ARCHIDORIS ODHNERI	1							
ARMANDIA BREVIS					1			
AUTOLYTUS VERRILLI	2							
CALLIOSTOMA LIGATUM		1						
CANCER MAGISTER	4	2	3	1	3	24	1	1
CANCER OREGONENSIS					1			
CANCER PRODUCTUS		1						
CAPITELLA CAPITATA	1				5			
CAPRELLA CALIFORNICA		3	1					
CAPRELLA LAEVIUSCULA	6	2						1
CIRRATULUS CIRRATUS				1	18	3	12	
CLINOCARDIUM NUTTALLI	2	1	2	1		1	1	
COROPHIUM BREVIS				3				
CRAB MEGALOPA	5	1	2	4		7	6	4
CRANGON NIGRICAUDA	31	10	2		2			
CRYPTOMYA CALIFORNICA		2	8	59	3	17	5	6
DENDRASTER EXCENTRICUS				1				
DIASTYLIS ALASKENSIS		1		12	2	1		5
DIASTYLOPSIS DAWSONI					1			
DORIDELLA STEINBERGAE	1							
EOHAUSTORIUS ESTUARIUS				1				
ETEONE LACTEA							1	
ETEONE LONGA							1	
EULALIA AVICULISETA	3				1			
EUPOLYMNIA CRESCENTIS	1	1			4	2	5	
EXOGENE LOUREI	2							
GEMMA GEMMA						15	1	
GLYCINDE PICTA	1		2	6	10	10	13	1
GNORIMOSPHAEROMA OREGONENSIS	1		1					
HAPLOSCOLOPLOS ELONGATUS			2	3	9	5	4	1
HARMOTHOE IMBRICATA	1		1		4	1		1
HARMOTHOE LUNULATA					1		1	
HEPTACARPUS BREVIROSTRIS		3						
HEPTACARPUS PALUDICOLA		16	1		1			1
HIPPOMEDON DENTICULATUS	1							
IDOTEA FEWKESI	1							
ISCHYROCERUS ANGUIPES			2					
LACUNA MARMORATA		1		1				1
LAMPROPS QUADRIPLICATA	1		9	5				
LIMNORIA ALGARUM								1
LITTORINA SCUTULATA		2						
LOPHOPANOPEUS BELLUS		1			1			
LOXORHYNCHUS CRISPATUS		1						
LUMBRINERIS CRUZENSIS					1			
LUMBRINERIS ZONATA	1					1		1
MACOMA INQUINATA	2	1	10	82	45	80	22	30
MAGELONA SACCULATA					1			
MEDIOMASTUS CALIFORNIENSIS			1		12	1	10	3
MELITA DENTATA	29	17	5		3	4		10
MESOCHAETOPTERUS TAYLORI						3	1	
MONOCULODES SPINIPES	2							
MYTILUS EDULIS	1	1	3		10	14	2	2
NAINERIS UNCINATA						1	1	
NASSARIUS MENDICUS				4				
NEMERTEAN UNID					3		3	
NEOAMPHITRITE ROBUSTA					1			
NEPHTYS CAECOIDES			3				1	
NUCELLA LAMELLOSA					1	1	1	
NUDIBRANCH UNID	3	1				1		1
ODOSTOMIA PHANEA				8	1	4		
OLIVELLA BIPLICATA	2		1					
OLIVELLA PYCNA	1		27	14		3		
OPHIUROIDEA UNID	1							
ORCHOMENELLA SP 1	3		17	36	15	10	8	3
OWENIA COLLARIS	1			26	5	18	44	5
PALEANOTUS BELLIS	7		1					
PARAPHOXUS EPISTOMUS	21		108	1	27	33	10	3
PARAPHOXUS SPINOSUS	6			11	3	3		
PARAPLEUSTES PUGETTENSIS	2	3	2	2	1			
PHOTIS BREVIPES	2		8	22	8	13	15	15
PINNIXIA SCHMITTI			3	16	3	8	4	1
PIONOSYLLIS GIGANTEA	1							
PISASTER OCHRACEUS					1			
PLATYNEREIS BICANALICULATA	3	1	6	3	5	4	1	2
PODOCERUS SP 1	5	3						
POLYCLADIDA UNID	6	5						
PONTOGENEIA INERMIS	5	3						
PRIONOSPIO CIRRIFERA								1
PRIONOSPIO MALMGRENI					3	3	3	1
PROTOMEDEIA ZOTEA				1	4	1	7	1
PROTOTHACA STAMINEA		1	9	21	5	49		2
PSEUDOPOTAMILLA SOCIALIS			1		1			
PYCNOGONID UNID	15	2	3		2	5		
PYCNOPODIA HELIANTHOIDES								1
RHYNCOSPIO ARENICOLA					1			
SABELLARIA SPINULOSA	1							
SAXIDOMUS GIGANTIUS				1				
SCOLOPLOS ARMIGER	1							
SPHAEROSYLLIS CALIFORNIENIS				1	1		1	
SYLLIS SP A			1			1	1	
TELLINA MODESTA			16	2	2	3		
TIRON BIOCELLATA			1					
TRANSENNELLA TANTILLA			1	1		2	1	

TRIP REPORT

SECTION 74 SEAFOOD PROCESSING STUDY

ALASKAN WATER QUALITY INVESTIGATIONS

JULY 25 THROUGH AUGUST 3, 1978

By

PETER M. MAHER

Edward C. Jordan Co., Inc.
Portland, Maine

July 25, 1978

On this day, I visited the two major salmon processing plants in Kenai, Alaska; Kenai Packing Company and Columbia Wards Fisheries. The purpose of these visits was to collect information relative to production, processing methods, processing periods, waste disposal and water use. The following account presents the information collected. Prior to visiting each plant, I contacted the plant managers to make arrangements to meet with them.

Kenai Packing is situated on the Kenai River. It is the last fish processor located on the river before it empties into Cook Inlet. Salmon is the only commodity presently processed at Kenai Packing. Like most major processors, Kenai Packing markets the canned and frozen varieties of salmon. No fish were being processed during my visit because the season was closed on July 21 to increase the escape rate for spawning Red salmon. They anticipated that fishing would be reopened on July 26 or 27, and processing would be initiated the following day.

The following information was provided by Mr. Fred McGill, Plant Manager, who was very cooperative throughout our discussion. Kenai Packing employs a maximum of about 270 people. The plant does not operate any fishing vessels, but purchases fish from approximately 150 privately-owned fishing boats. Only a portion of the people employed at Kenai Packing are provided with housing and meals at the cannery.

The last three years of salmon production at Kenai Packing is summarized as follows:

	1977	1976	1975
Hand-Butchered	923,860 lbs	349,849 lbs	263,558 lbs
Mechanically-Butchered	6,996,000 lbs	5,532,384 lbs	3,691,425 lbs
Salmon Roe	389,434 lbs	225,814 lbs	189,175 lbs

The above figures represent finished product weights. For raw production figures, Mr. McGill indicated that 11.5 percent could be added to the hand-butchered figures, and 43 percent could be added to the mechanically-butchered product which is subsequently canned. The processing of hand-butchered salmon yields approximately 90 percent finished product and 10 percent waste by weight.

About 90 percent of the hand-butchered salmon produced by Kenai Packing is exported to Japan. Fish exported to Japan are generally Red salmon with the head-on, as opposed to the remaining 10 percent which are shipped to Seattle with the head-off. The quantity shipped to Seattle represents mostly King salmon. All of the roe (eggs) is exported to Japan.

Mechanically-butchered salmon yields approximately 70 percent finished product and 30 percent waste by weight. Pink salmon is always canned. The Silver and Chum species are usually canned, but at times they are hand-butchered and frozen for export to Japan. Again, the roe is cured, packaged and exported to Japan.

Average production figures are difficult to develop due to the variability in salmon fishing. Mr. McGill estimated the average weight of hand-butchered salmon processed to be 8,000 lbs of raw product per day and 100,000 lbs of mechanically-butchered salmon per day (raw product). He also estimated the average number of processing days at 20. Typically, processing will take place during one shift, consisting of 6 to 8 hours.

During approximately seven days per year, Kenai Packing reaches peak production levels. On these days, approximately 15,000 lbs per day of hand-butchered salmon and 300,000 lbs per day of mechanically butchered salmon is processed (weights represent raw product). One 12-hour shift per day is operated during peak production periods. The normal canned salmon processing period in this area extends from June 25 to August 10.

Kenai Packing utilizes three Model G iron chinks to mechanically butcher salmon. Each chink has a capacity of approximately 70 fish per minute. The chinks supply fish to six canning lines which may all be operated simultaneously. There is one tall (15-1/2 oz), three 1/2-pound (7-3/4 oz), and two 1/4-pound (3-3/4 oz) lines.

Hand-butchered salmon is frozen in seven Dole contact (plate) freezers which have a total capacity of 3,120 fish (624 pans at 5 fish per pan). Three air-blast freezer rooms, each with a capacity of 100 tons per 24 hours are also utilized.

There are no byproducts separated from the waste stream at Kenai Packing with the exception of a small amount of salmon heads for oil extraction. According to Mr. McGill, all waste solids are ground and discharged via two outfalls. Canning line wastes are washed into floor drains which direct the wastewaters into three wet wells located beneath the iron chinks. Waste solids from the iron chinks are also directed to the three wet wells. Wastewater containing the solids then flows into a main collection sump from which the solids are screw conveyed approximately 10 feet to an Autio grinder. Once ground, the solids are flushed through a 10-inch outfall which discharges into the Kenai River, a distance of approximately 75 feet. The outfall is in very poor condition and several leaks were noted by SCS Engineers while sampling in the area of Kenai Packing. SCS Engineers also mentioned that an extra length of pipe was added to the outfall on the day preceding my visit. Prior to the installation of the additional pipe length, the outfall discharged above the low tide level. Wastes from the roe processing building are also directed to this outfall.

Waste solids generated by the hand butchering operation are discharged via a separate 8-inch, 40-foot outfall. These solids are washed into floor drains which discharge to a wet well. A 7-1/2 horsepower DeLumper grinder pump had been used to grind these solids prior to discharge. Prior to my visit, the DeLumper grinder had been removed from operation because it often became clogged. Mr. McGill indicated that a Vaughan grinder pump has been ordered to replace the DeLumper. The 8-inch outfall appears to be in good condition with no leaks noted. According to Mr. McGill, the two grinders and respective outfalls have been in operation for more than 15 years.

Several non-point discharges were observed at the Kenai Packing facility. From visual observations, these appeared to be water used for fluming and washdown with some flow originating at the roe building.

In-plant modifications for reducing water use are presently absent at this processing plant. Hoses were continuously running and there are no nozzles of any kind being employed. Kenai Packing obtains its water from six wells, each having a 300 gpm pump. The May 1978 NPDES monitoring report estimated an average water use of 600,000 gpd.

Columbia Wards Fisheries (CWF) is also located on the Kenai River. This facility discharges the furthest upstream of all the processors situated along the Kenai River. CWF processes a small amount of herring in addition to its major commodity, salmon. Salmon is marketed as both the frozen and canned products. No fish were being processed during my visit because fishing was temporarily closed on July 21.

The following information was provided by Mr. Ray Landry, Plant Manager. This is Mr. Landry's first year as plant manager of the Kenai facility. CWF is a self-contained cannery which houses, feeds and clothes the majority of the workers. The cannery owns 30 fishing vessels and buys fish from 120 privately-owned boats. Mr. Landry was very cooperative in supplying the information presented below.

Historical data regarding production could not be provided by Mr. Landry because this information is kept in the main office located in Seattle, Washington. He thought that this data could be obtained through the mail or over the phone at the beginning of September. The 1978 production information through July 23 is as follows:

Hand-Butchered Salmon	1,000,000 lbs (round)
Mechanically-Butchered Salmon	2,390,328 lbs (round)
Frozen Herring	120,000 lbs (round)

Herring is processed early in the year prior to initiating salmon operations. The fish are frozen in the round for export to Japan. Herring has not been processed every year.

Kenai Packing processed 130,000 lbs of frozen (custom) salmon for CWF. The gurry from the hand-butchered fish were disposed of by Kenai Packers. Approximately 20,000 lbs of salmon were custom frozen by Kenner Packers with the gurry transported to CWF for disposal.

All of the hand-butchered salmon processed at CWF is shipped to Seattle, Washington. The heads are generally removed prior to shipment. Mr. Landry estimated the percent yield for hand-butchered salmon to be approximately 82 percent. The percent yield for canned salmon was estimated to be 70 percent. Most of the hand-butchered fish are King and Red salmon. The canned product includes Pink, Chum and Silver salmon. All salmon roe is processed and exported to Japan for sale.

Average production levels at CWF are difficult to estimate because of the variability in fishing. CWF processes fish a short time after they are delivered to the plant due to the limited storage facilities. During the current year, CWF has operated for 29 canning days and 35 freezing (hand-butcher) days. All of the herring was processed over four days. By dividing the number of processing days into the raw product figures, average production levels are approximately 24,000 lbs of hand-butchered salmon per day, 82,000 lbs of canned salmon per day and 30,000 lbs of herring per day.

Production reaches peak levels at CWF during seven days per year. During this period, approximately 40,000 lbs per day of hand-butchered salmon and 430,000 lbs per day of mechanically butchered salmon is processed with weights representing raw product. Two 12-hour shifts per day are operated during peak production for hand butchered fish. One shift per day for 12 to 16 hours is operated during peak production periods for mechanically-butchered salmon. The normal salmon processing season extends from around June 26 to August 14 at CWF. Herring is normally processed during the middle part of May.

CWF has three Model G iron chinks available to mechanically butcher salmon. Only two chinks may operate at one time. Each chink has a capacity of approximately 70 fish per minute. The chinks are set-up to supply fish to two canning lines. Any combination of two tall, one 1/2-lb or one 1/4-lb canning lines may be utilized. The one-pound lines have a capacity of 250 cases per hour. The half-pound lines have twice this capacity and the one-quarter pound lines have four times this capacity. According to Mr. Landry, there are 72 lbs of raw product per case of 1-lb cans, 36 lbs of raw product per case of 1/2-lb cans and 18-lbs of raw product per case of 1/4 lb cans.

Hand-butchered salmon is frozen in three Dole contact (plate) freezers which have a total capacity of approximately 15,840 fish (288 pans at 5.5 fish per pan with head-off).

A small amount of oil is produced from rendered salmon heads. Other byproducts are not recovered from the wastes generated at CWF. According to Mr. Landry, all waste solids are ground and discharged through the outfall. Solids from the canning lines and hand-butchering operations are washed into floor drains which discharge into wet wells located beneath the iron chink area. All wastes then flow into the main collection sump. A 10-Hp, 800 gpm Vaughan pump grinds the gross solids, which are then discharged through a 6-inch, 100-foot PVC outfall into the Kenai River. The outfall appeared to be in good condition and no leaks were observed. The Vaughan grinder was installed this year and replaced a DeLumper grinder. A small Autio grinder handles the heads for the oil extraction process. The rendered solids are discharged via the same 100-foot outfall.

No in-plant measures for reducing the use of water are presently employed at CWF. Process water is obtained from three wells. Accurate water use records are kept at CWF. During the first 24 days of July, the average daily flow was 290,379 gallons. Maximum daily flow was 681,900 gallons and minimum daily flow was 81,900 gallons.

July 26, 1978

This day was spent on the charter boat, Tres Cher, observing the water quality sampling program being undertaken by SCS Engineers for the Kenai River. Four representatives of SCS took part in the water quality sampling including the Technical Project Manager, Michael Caponigro. Mr. Caponigro, Terry Boston and Libby Lundt are all full-time employees of SCS. Steven Petrich was hired as a private consultant to assist in this work. Mr. Petrich is a M.A. candidate in Marine Biology at California State University, Long Beach.

Samples were taken at stations located in the Kenai River in the vicinity of Kenai Packers and Columbia Ward Fisheries. Tidal fluctuations in the Kenai River are greater than 20 feet. The bottom is generally comprised of cobbles and the water is very turbid since the river is fed for the most part by glacial streams. Visibility is less than one foot at all times. Because of the high tidal fluctuations, the currents in the river are strong. The intensity of the currents restricted most of the sampling effort to approximately 1.5 hours early in the morning, and one hour during the late afternoon. These time periods coincided with slack tide when the currents are at a minimum. Considerable effort was required to obtain representative duplicate sediment samples even at slack tide, due to the presence of large cobbles which would jam the benthic grab in an open position.

Samples were obtained at predetermined stations in front of Kenai Packers and Columbia Ward Fisheries. Neither plant was processing fish during the sampling program. There were 12 sampling stations located by Mr. Caponigro in front of Kenai Packers. One station was located in the vicinity of each outfall operated by Kenai Packers. Stations located across the river from this facility served as control sites. The remaining stations were selected along the near shore (Kenai Packers) and at mid-river transects. Additionally, three stations were located in the immediate area of Columbia Ward Fisheries with one at the discharge and the others at upstream and downstream locations.

Three types of samples were taken at each station. Duplicate water chemistry samples were collected at three different depths. Aliquots were taken at surface, mid and bottom depths for each station. The samples were obtained with a Van Doren bottle for the following analyses: pH, dissolved oxygen, salinity, temperature, nutrients and sulfides. On board, dissolved oxygen concentrations were determined by the modified Winkler titration method and salinity analysis was accomplished with a refractometer calibrated against a standard sea water sample. Temperature and pH were measured with stem thermometers and a field pH meter, respectively. Samples for nutrients and sulfide analyses were preserved and iced for shipment to the Dames and Moore laboratory in Fairbanks, Alaska. When facilities were available, water samples were frozen following collection.

Duplicate sediment chemistry samples were also taken at each station. These samples were obtained with a 0.1 m^2 Van Veen bottom sampler operated from a winch on the boat. Each duplicate was pulled up from the bottom and deposited into a galvanized steel tub. If the grab was considered to be representative (based upon size and amount of sample), a plastic jar was filled (approximately 500 ml) with bottom sediment to be analyzed for hydrogen sulfide, total Kjeldahl nitrogen, total organic carbon and volatile solids. A separate jar was filled for determining particle size distributions by SCS Engineers at Long Beach. Benthic samples were obtained in the same manner as sediment chemistry samples. Duplicates were taken for each station. Deposition of each sample was accomplished in a galvanized steel tub. The supernatant was decanted into a plastic pail with a screened bottom. The remaining sediment was then washed into five-gallon plastic pails along with the screened material from the supernatant. Sample preservation was accomplished with buffered formalin. Benthic analysis includes identification of the species present and population density of specific microorganisms.

July 27, 1978

To obtain general information concerning processing facilities, population and work force for the Kenai area, I visited city hall on this day. Currently, there are four salmon processors operating in Kenai, Alaska, all of which are located on the Kenai River. Columbia Wards Fisheries and Kenai Packing Company are the major ones. Dragnet Fisheries and R. Lee Seafoods are much smaller operations. At the time of my visit, both R. Lee and Dragnet were idle.

Based on a 1976 census, the city of Kenai has a population of 5,000. Approximately 2,700 employable people reside within the city limits. Of these, 2,200 or 81 percent are employed. This information was obtained from the Kenai Peninsula Borough Planning Agency.

There is one landfill operated by the Borough which is located within the Kenai city limits. Road conditions and accessibility to the landfill are good. The city has been operating a primary treatment plant since 1972, which at the present time, does not have the capacity to accomodate flows from the local seafood processors. Information concerning the average number of days per year acceptable weather conditions for barging occur could not be provided.

R. Lee Seafoods is located upstream of Columbia Wards Fisheries and on the same side of the Kenai River. Salmon is manually butchered at R. Lee and frozen. Eggs are extracted, boxed and exported to Japan. Two butchering tables are used to process up to 150,000 lbs of raw product per day at this facility. Three Dole plate freezers are employed to generate the final product. Waste solids are ground and discharged. An Autio 1101 grinder is located outside of the processing building. The discharge pipe (6" PVC) was disconnected on the shore approximately 30 feet from the grinder.

July 31, 1978

The charter boat Tres Cher arrived in Cordova from Kenai on July 29. The Cordova water quality sampling effort began on July 30 and was terminated on August 2.

On this day, I was aboard the Tres Cher to observe the sampling effort and videotaping of the bottom areas adjacent to the outfalls of St. Elias Ocean Products, North Pacific Processors, Morpac, Inc., and New England Fish Co. (NEFCO). The SCS Engineers crew was joined on board by three divers from Industrial Underwater Services of Tacoma, Washington.

There were 20 sampling stations selected, including three control stations in Orca Inlet. Four of the stations were located at the outfalls operated by the four processing plants in Cordova. The control stations were located across the channel approximately 2,000 meters from the processing plants. The remaining stations were located at distances of 100 to 300 yards from the shore along transects parallel to the shore and included stations which were up-current and down-current from the discharge points.

The sampling procedures for collecting water, sediment and benthos samples employed at Cordova were identical to those in Kenai. Since Orca Inlet experiences only 10-foot tides, the sampling was more routine than that experienced in Kenai.

The divers videotaped the areas surrounding each outfall pipe at varying distances (up to 50 feet). The videotaping was accompanied by an audio account which was also recorded. The following is a summary of observations as seen on the TV monitor on board the boat and supplemented by the divers comments.

The St. Elias outfall is located approximately 10 feet from the left side of the dock area as observed from off-shore. The pipe is 4-inch

PVC and positioned a few inches off the bottom. The pipe end is jagged, apparently the result of a tender shearing it earlier this summer. At the very end of the outfall, there was no significant buildup of waste material observed. Only a very few crab shells were located at this point. A number of flounder and starfish were observed to be feeding off small solids discharged from the outfall. Moving radially away from the end of the outfall, the diver noted that the bottom consisted mostly of crab shells covered with one-half inch of silt. As he moved out to a distance of 22 feet, the depth of material (shells) increased to approximately 18 inches. At a distance of 28 feet, old fish heads were observed every 2 to 3 feet. These deposits of large solids were probably the result of dumping wastes at the dock face as opposed to discharges from the outfall. The visibility also improved and the depth of material decreased. At 40 feet the bottom was noted to be sandy and barren with an absence of significant animal life. A stronger current was detected at 40 feet and the visibility improved, approaching 3 feet.

Next, the diver filmed the bottom areas at the other side of the St. Elias pier. St. Elias has been dumping crab shells overboard due to a breakdown in its grinder. Close to the pier, 80 percent of the bottom was covered mostly with whole crab shells. At the center of the pier and in 19 feet of water, the bottom was 80 percent covered with 8 inches of crab shells. The shell density began to thin out at a distance of 10 feet from the pier. Fifteen feet from the pier, there was 50 percent bottom coverage with crab shells. One fish head was observed 40 feet from the pier and approximately 5 percent of the bottom was covered with crab shells.

Very few shells were detected beneath the St. Elias pier. The divers collected samples for sediment chemistry and benthic analysis at the outfall as well as the location where crab shells were being dumped.

The North Pacific Processors outfall extends to the end of the dock and is approximately 40 feet north-northeast of the dock face. The pipe situated approximately 10 inches off the bottom is 4-inch galvanized steel. As a result of discharging wastes through the outfall, a 10-foot wide by 2-foot deep trough developed in the ocean bottom which extended from the outfall. A large quantity of unground, gross fish solids were noted in the area of the galvanized steel pipe. The depth of solids, including crab shells and unground fish parts, increased from 8 to 12 inches at the discharge to 4 feet at a radius of 40 feet. The accumulation of solids continued farther than this distance and the termination could not be seen by the diver. At a distance of 10 feet from the discharge pipe, 90 percent of the solids were crab shells. At any one time, approximately 50 flounder could be observed feeding on the debris. The divers did obtain bottom samples at this location.

The discharge line originating at Morpac, Inc. is 4-inch PVC which extends horizontally for approximately 200 feet directly beneath the dock and makes a 90-degree vertical turn into the water at the very end of the dock. The pipe extends downward and terminates 5 feet from the bottom. The discharge has scoured a 2-foot hole directly below the pipe. The solids were observed to be 6 to 12 inches deep of finely ground fish parts and very few crab shells. No gross solids were encountered. Moving away from the outfall, the solids depth increased to approximately 3 feet at a distance of 15 feet. Very little marine life was encountered at Morpac.

August 1, 1978

Visits were made to the three seafood processors operating during the 1978 salmon season in Cordova, Alaska; St. Elias Ocean Products, North Pacific Processors, Inc., and Morpac, Inc. All three processors are located on Orca Inlet which empties into Prince William Sound and the Gulf of Alaska. Prior to visiting each plant, I contacted the plant managers and made arrangements to meet with them.

At St. Elias Ocean Products (SEOP), I met with Walter Crow, the Plant Manager and Jim Poor, the Plant Foreman. SEOP employs a maximum of 110 people during the peak of the salmon processing season. The peak usually occurs around the last two weeks of July when pink and chum salmon are canned. Approximately 50 people are housed at SEOP. All fish and crab are purchased from independent fishermen which is common practice for the processors in Cordova. St. Elias initiated processing in its new $3 million plant this year. For the previous eight years, processing took place in an old ferry tied up adjacent to the new plant. SEOP processes Tanner, Dungeness and a very small amount of King crab, hand-butchered and mechanically-butchered salmon, halibut, and herring. As predicted, this season has been a poor year for salmon fishing. During my visit, fishing was closed because the Pink run had just finished and the Silver run had not yet started. Very few Pink salmon were caught as compared to previous seasons. Historical production data could not be provided by SEOP. According to Mr. Crow, this data can be obtained from the main office in Seattle.

Generally, crab processing begins in mid-November at SEOP. Tanner (Snow) crab is processed from this date through June 1. In 1978, 2.3 million lbs of live crab were processed. Approximately 20 percent of the raw product is converted to meat while 80 percent is discharged as wastes. Depending on the market conditions, the meat is either canned or frozen. Of the 1978 Tanner crab meat production, 90 percent was canned and 10 percent was frozen. Last year's production placed emphasis on the frozen product with only 10 percent being canned. There are no peak processing days for Tanner crab. Approximately 30,000 lbs of raw product is processed during one 8-hour shift per day throughout the season. Rollers are used to remove the meat from the shell.

This year was the first time that significant amounts of Dungeness crab were processed at SEOP. Dungeness crab processing starts around June 1 and extends to mid-September. It is packaged as either frozen whole crab or crab sections. Since June 1, 1978 approximately 1 million lbs of live Dungeness crab have been processed. Mr. Crow expected that another 500,000 lbs would be processed before the end of the season. When processing sections, approximately 35 percent of the live weight becomes waste. There is essentially no waste when Dungeness crab is processed whole. Since there is no peak processing days for this commodity, about 20,000 lbs of raw product is processed in one 8-hour shift per day throughout the season at SEOP.

At SEOP, salmon processing begins in mid-May. The majority of the fish processed from this date through early July are hand-butchered for the frozen market. Approximately 90 percent of the fish hand-butchered are Red salmon. Almost all of the Red salmon are frozen with the head-on for export to Japan. The remaining 10 percent of the hand-butchered fish are King, Silver and Chum salmon which are beheaded and marketed within the United States. Head-on fish yield approximately 89 percent product, while head-off fish yield between 80 and 83 percent final product depending on the species. Average production of hand-butchered salmon approximates 30,000 lbs during an 8-hour shift. During peak production days, approximately 60,000 lbs of salmon are hand-butchered in an 12-hour shift. At SEOP this occurs only four or five days per year.

Salmon which are mechanically-butchered for canning are normally processed during a three to five-week period beginning in early July and running through mid-August. The majority of the fish canned at SEOP are Pink and Chum salmon. Mechanically-butchering salmon yields approximately 77 percent final product at SEOP. During the canning season, average production approximates 80,000 lbs of raw fish in an 8-hour shift. Approximately 350,000 lbs of salmon are canned at SEOP during peak production. Maximum production occurs over an 14-hour shift during an average of six days per year.

The halibut fishing season is regulated by the federal government and is usually opened for 3 two-week periods. Halibut is butchered by the fishermen on the boat so there is essentially no solids generated by the processing plants. Last year, SEOP froze approximately 100,000 lbs of halibut. To date, SEOP has processed approximately 60,000 lbs.

Approximately 200 tons of herring were frozen in the round in 1978 at SEOP. The entire quantity of herring was processed during four days in May. The bulk of the processing time is involved with freezing the fish. At the St. Elias facility, crab, halibut and salmon can be processed simultaneously.

Since the St. Elias plant is a very modern facility, it utilizes the latest in processing equipment. It is well laid out and operates with relatively low water use.

On the day of my visit, SEOP was processing a small quantity of Dungeness crab. All crab is brought into the plant by bucket and crane.

Seven large stainless steel tanks hold crab and fish until they can be processed. Crab is maintained alive by pumping sea water through the tanks. The sea water is discharged directly beneath the pier supporting the processing facility. For whole crab processing, the live crab is washed prior to cooking. The washing process consists of spray jets located directly above a conveyor line for the crab. A continuous stream of water runs through the conveyor line and is directed into floor drains located beneath the processing line. The washed crab is next conveyed into a stainless steel tub of boiling water for cooking (a flow-through cooker). From the cooker, crab is scrubbed with mechanically rotating brushes and washed once again. The Dungeness crab is then tied with rubber bands for freezing whole.

When processing sections, crab is butchered prior to the flow-through cooking process. The operation continues in the same manner as whole crab from that point on. The brine freezing process has a capacity of 15,000 lbs of whole crab in eight hours, and 25,000 lbs of crab sections (raw product) during the same period.

Tanner crab is handled utilizing a process similar to that employed for Dungeness species except for the butchering operation. Prior to cooking, the crabs are butchered and the body and viscera are discarded as waste. Subsequently, the legs are removed from the body sections by sawing. After precooking, legs are fed through rollers which extract the meat from the shells. The crab meat is then either frozen or canned depending on market demand. For freezing, the meat is cooked a second time, rinsed, frozen and packaged. Canned meat is hand-packed and retorted. According to Mr. Poor, crab shells are belt conveyed to the 30 hp Vaughan grinder pump.

Salmon is unloaded from the fishing vessels via a Temco pneumatic system. From the Temco unit, the fish are belt conveyed to the holding tank for subsequent processing. The salmon are washed into a wet sluice which transports the fish to an elevator which feeds another conveyor. Two Model G iron chinks are available for butchering in addition to a hand-butchering table. According to Mr. Poor, very little waste from the chinks hits the floor. Most of the solids are channeled into the sump which feeds the grinder pump. Sliming table wastes are washed directly into a drain which directs them to the grinder. St. Elias packs salmon in 4, 1, 1/2 and 1/4 pound cans. This facility is capable of simultaneously operating any combination of two canning lines, except the four and one-pound lines. The four-pound cans are hand packed. Canning line wastes are washed into floor drains which flow to the grinder pump. Solids from the hand butchering table are dry conveyed to a floor drain which channels them to the grinder pump. St. Elias has installed spray nozzles on 70 percent of the hoses utilized in the plant. Mr. Crow expects to provide nozzles for the remaining hoses.

St. Elias employs two blast freezers for salmon, halibut and herring. The combined maximum capacity of the two freezers is 60,000 lbs of fish.

No byproducts are recovered at the St. Elias facility. All fish solids, crab shells and washwater collected by the 57 floor drains available throughout the facility are directed to a central wet well. The grinder pump discharges through a 4-inch PVC outfall into the Inlet. According to Mr. Crow, the outfall extends a distance of 200 feet.

The grinder and wet well are located beneath the dock in the vicinity of the sliming tables. Last year, a tender rested on the outfall at low tide and sheared it 10 feet from the end of the pier.

St. Elias uses water supplied by the city of Cordova for its processing operations. The meter which measures water use was installed on June 28, 1978. Since that date it has recorded an average water use of 207,700 gpd, a maximum consumption of 396,300 gpd and a minimum use of less than 1,000 gpd.

At Morpac, Inc., Mr. James Forsell, Plant Manager and Mr. John Hewett, General Foreman were available to meet with me. Morpac employs a maximum of 85 people during peak processing periods. Employees are not housed at the cannery. Production data could not be supplied because the files are maintained in Seattle. Mr. Forsell indicated that the data could be obtained from the Seattle office by mail.

A small amount of whole Dungeness crab was being processed the day of my visit to Morpac. This plant processes Dungeness crab whole and in sections, while Tanner crab is marketed as sections. The Dungeness crab season normally extends from July 1 through October 14. So far this year, Morpac has processed approximately 450,000 lbs of Dungeness crab. Production involves the packaging of frozen whole crab or frozen sections. The Tanner (Snow) crab processing season normally occurs from January 10 to May 30 at Morpac. Approximately 1,150,000 lbs of Tanner crab was processed as frozen sections during 1978. Morpac does not market the frozen or canned meat variety of this specie. Average Tanner and Dungeness production approximates 40,000 lbs of raw product per day for each commodity. Typical days involve one 6-hour shift for either type of crab. During peak production periods, approximately 65,000 lbs of live crab are processed per day over an 8-hour shift. Since crab can be kept alive for relatively long periods, the occurrence of peak days is rare. When processing Dungeness crab sections, approximately 60 percent of the live weight is packaged. For Tanner crab sections, the useable portion of the raw product approximates 58 percent.

The salmon processing season extends from May 15 through the first week of September. Through July 14, the majority of the fish processed are Red and King salmon which are hand-butchered and frozen. By August 1 of this year, approximately 550,000 lbs of Red salmon had been hand-butchered Japanese style (head-on), while 165,000 lbs of King, Chum and Pink salmon were hand-butchered American style (head-off). Most of the American style fish were King salmon. Japanese style fish yield approximately 88 percent final product as opposed to American style fish which have a 75 percent yield.

The canning season normally extends from the first week of July through the middle of August. Pink and Chum salmon are the two varieties which are normally canned. As of August 1, 1978 approximately 1,585,000 lbs of raw material had been canned by Morpac in two can sizes. When packing tall (1-lb) cans, the product yield is approximately 65 percent. One-half pound cans will generally realize 70 percent yield. Mr. Forsell would not provide any information relative to average salmon processing due to fluctuations in the industry. The maximum production day for hand-butchered fish was 70,000 lbs of raw product which occurred in 1977. Most peak days involve the processing of approximately 45,000 lbs of salmon over one 14-hour shift. On the average, this may occur three days per year. Peak canning days entail the processing of approximately 200,000 lbs of Pink salmon in one 14-hour shift. During the season, this usually takes place on six or seven days. Morpac can process Dungeness crab and salmon simultaneously.

Herring was processed for three days during April of 1978 at Morpac. The herring were frozen in the round for export to Japan. Approximately 65 tons was processed during this time.

Crab processing methods and equipment are typical for the industry. Morpac processes both Dungeness and Tanner crab either as a whole product or for sections. Meat products are not processed at this facility. Morpac employs a process which is similar to the operation at St. Elias. However, Morpac does use batch cookers instead of a flow-through cooker. For crab, one brine freezer which has a capacity of 3,000 lbs finished product per hour is available. The crab operation at Morpac does not appear as efficient as the St. Elias set-up. Processing equipment is spread out over a large area. Spillage is frequent and the floors were littered with waste during the day of my visit. Most of the floor drains in the crab area are connected to the grinder; however, the connections leak and a significant portion of the waste spills into the water directly under the crab area.

Morpac processes herring, crab, salmon roe and hand-butchered salmon in a building which is separate from the canning operations. Hand-butchered salmon, Tanner crab and herring are subjected to blast freezing. Approximately 70,000 lbs of raw salmon may be frozen during two shifts. Waste solids are washed into several floor drains which empty into an Autio 801 grinder located beneath and adjacent to the hand-butchering table. The grinder is in extremely poor condition and was not operational at the time of my visit. They plan to replace it next year with a Vaughan grinder pump. No spray nozzles are employed at Morpac and water use appears to be excessive. Ground solids from the Autio 801 are pumped to a main collection sump from which they are again pumped to the end of the dock, a distance of 200 feet from shore. The pipe is approximately five feet from the bottom and is exposed at low tide. The discharge pipe is 6-inch PVC in good condition and no leaks were observed.

Salmon is canned in a larger, separate building. Most fish are unloaded using a Temco system; however, Kings are unloaded with buckets in a manner similar to crab. Salmon operations employ the same procedures as those noted for St. Elias. Fish are flumed from seven holding bins to belt conveyors. The remaining transport operations are accomplished by dry conveying. Morpac utilizes a Model K (90 fish per minute) and a Model G (70 fish per minute) iron chinks. Both can be operated simultaneously, but this occurrence is rare. Salmon is canned by either the one-pound or one-half pound line, but the two lines are never operated at once. Heads removed by the chink fall into a pipe which connects to an Autio 1101 grinder. All other solids are washed into floor drains which connect to the same grinder. The mechanism is located beneath the pier and in the vicinity of the sliming tables. Flow from the Autio 1101 enters the main collection sump where it combines with the flow from the Autio 801 for discharge via the outfall.

Byproducts, such as Salmon oil, are not recovered at Morpac. All waste solids are ground for discharge. The crab grinder (Autio 801) has been in use since 1969. The salmon grinder (Autio 1101) and outfall was installed in 1974.

Morpac purchases its water from the city of Cordova. Water use in April, 1977 (peak Tanner crab season) was measured at 35,900 gpd, average; and 210,000 gpd, peak. Water use in July 1977 (peak salmon canning season) was measured at 137,100 gpd average; and 325,000 gpd, maximum.

Later, I met with Mr. Ken Roemhildt, Superintendent and Mr. Al Fulton, General Foreman at North Pacific Processors, Inc. (NPP). Both gentlemen went to great lengths to explain to me their reason for the decline of halibut and crab catches in Orca Inlet over the past years. According to them, the implementation of grinding has decreased the available food supply for these species.

The NPP plant employs between 10 and 100 people throughout the year. Approximately 40 people are housed and fed at the plant during peak salmon processing periods. All fish and crab are purchased from independent fishermen.

A small amount of Dungeness crab was being processed at NPP during the day of my visit. The NPP plant processes Dungeness crab (whole and sections), Tanner crab (canned and frozen meat, frozen claws), hand-butchered salmon, canned salmon, halibut and herring (frozen in the round). This year was the first time herring was handled by the NPP facility.

Salmon production data provided by NPP was given in terms of total number of cans packed for each species. Approximately 75 lbs of whole fish are required to fill one case (48, one-pound cans). All conversions have been based on this figure. Production at NPP in pounds of raw product for 1975 through 1977 is as follows:

	1977	1976	1975
Whole cooked Dungeness crab	13,650 lbs	0 lbs	28,775 lbs
Cooked Dungeness crab sections	4,714 lbs	0 lbs	4,927 lbs
Canned Tanner crab meat	0 lbs	N/A	387,600 lbs
Frozen Tanner crab claws	0 lbs	83,256 lbs	0 lbs
Hand-butchered salmon	1,392,760 lbs	754,389 lbs	550,325 lbs
Mechanically-butchered salmon	6,249,959 lbs	4,929,801 lbs	4,517,068 lbs
Frozen halibut	20,624 lbs	21,368 lbs	40,430 lbs

In 1978, 252,285 lbs of herring was frozen in the round and exported to Japan. Another 272,000 lbs of herring was frozen and sold for bait. The herring season was short term and occurred from April 10 to April 20. It was recommended that the production figures be checked with records kept in Seattle.

Crab processing begins November 15 at NPP. Tanner crab is processed from this date through April 15, and is marketed as frozen or canned meat. When canning, approximately 23 percent of the raw product is converted to final product while a slightly greater yield is realized when freezing meat. Average production of Tanner crab approximates 14,000 lbs of raw product per day. This is accomplished during one 7-hour shift. During peak Tanner crab season, 35,000 lbs of raw product is either canned or frozen during a 12-hour shift. Peak processing days generally occur six times per year.

Dungeness crab is processed in small incidental quantities at NPP. When processing sections, approximately 70 percent of the raw product is recovered with the remainder discarded as waste. Dungeness crab processing is usually limited to three days at the beginning of September. During an average day, approximately 10,000 lbs of raw crab is processed in one 7-hour shift.

At NPP, salmon processing season is initiated on May 15 and extends through August 5. Most of the fish processed are hand-butchered and frozen through July 15. Approximately 60 percent of the fish are butchered Japanese style. Most of these fish are Red salmon with a small portion being Silvers which are processed at the very end of the salmon season (August 1 to August 7). The majority of the canned fish are Pink and Chum salmon with a small amount of Reds. Most of the canning is accomplished from July 15 through August 5. Head-on salmon have an approximate yield of 79 percent, while head-off and canned products yield approximately 68 and 65 percent, respectively.

Approximately 30,000 lbs of whole salmon are hand-butchered during an average day at NPP. Typical days consist of one 8-hour shift and occur approximately 45 days per year. About 150,000 lbs of whole salmon are canned during an average day. An average canning day occurs 20 times per year and one 12-hour shift is necessary to achieve this production. At peak processing levels, 100,000 lbs of whole salmon is hand-butchered in one 12-hour shift. This occurs three or four times per year. Approximately 400,000 lbs of whole salmon are processed for canning in one 18-hour shift during peak conditions. Maximum canning days occur six to eight times per year. With its current set-up, NPP cannot process more than one commodity at any one time.

Dungeness crab processing at NPP occurs in the same manner as that adopted by Morpac, Inc. As previously mentioned, Dungeness crab is processed on a small scale as a fill-in during the salmon season. Processing techniques were observed to be inefficient in terms of waste management. The butchering area was spread out and solids littered the floor area. The relative distances between the areas where the crab is butchered, washed, cooked and frozen appeared to be excessive for an efficient operation. However, this could be attributed to the intermittent processing of Dungeness crab on a random basis between salmon runs. According to Mr. Fulton, Tanner crab is processed in the same manner as at St. Elias, except NPP employs batch cookers. The meat is extracted from the legs through the use of rollers.

Fish are transported to holding tanks by an elevator conveyor and wet fluming. Two Model G iron chinks are used to mechanically-butcher salmon at NPP. Butchered fish are transported to one sliming table and subsequently conveyed to three canning lines (1/4, 1/2 and 1 lb). Normally, the one-pound line can handle salmon under normal conditions. Depending on the market conditions, the 1/4 and 1/2 lb lines can be run simultaneously.

Five Dole plate freezers are employed at NPP for producing frozen salmon. These units have a maximum total capacity of 40 tons per day over three shifts. An additional plate freezer is used for fish and Tanner crab processing. This unit can handle 20 tons of salmon during a single shift per day. A six basket brine unit is used to freeze crab in the shell.

NPP grinds approximately 85 percent of the waste salmon heads in an Autio grinder for shipment to Seattle. Approximately 500 tons per year are frozen for future use in petfood production at a Seattle facility.

According to Mr. Roemhildt, all other solids and waste materials are ground and discharged through a 100-foot, 4-inch galvanized steel outfall. The outfall originally extended 240 feet into the ocean; however, a tender severed 140 feet of pipe in the fall of 1977. NPP utilizes a 30 hp Vaughan grinder pump which is located beneath the crab butchering areas.

The galvanized steel outfall has been in use for a period of four or five years. The divers inspection of the outfall revealed that it extends approximately 200 feet from shore or about 60 feet from the grinder pump. Moreover, the actual amount of waste which enters the grinder is not 100 percent. Upon visual inspection of the plant, I noticed there was only one collection flume which extends from the crab butchering area, beneath the salmon holding tanks and continues to the end of the canning lines. The majority of the floor drains discharge directly beneath the pier into the water below. These drains are located in the crab butchering and processing area, the egg building and the hand-butchering area. None of the floor drains present in these areas were found to be connected to the main flume which direct flows to the grinder pump.

NPP purchases process water from the city of Cordova. Mr. Roemhildt estimated the average water use during the crab season to be 40,000 gpd with a peak consumption of 50 to 55,000 gpd. Average water use during the salmon canning season is 250,000 gpd and maximum usage was estimated at 600,000 gpd.

August 2, 1978

On this day, I met with Mr. James Jacobsen, Plant Manager for the New England Fish Company (NEFCO) plant. NEFCO is located approximately 3 miles along Orca Inlet from Cordova. Until six years ago, the NEFCO plant was isolated from the city and the only way one could reach the plant was by boat. Normally, 125 people are employed during the salmon canning season at NEFCO with 80 percent being housed at the cannery. NEFCO is the largest processor of salmon in the Cordova area. Other commodities, such as crab, are not handled by this facility. No salmon were being processed by NEFCO this year due to the poor fishing season. According to Mr. Jacobsen, large quantities of fish are required to operate at a profit. Arrangements were made with St. Elias to process the fish purchased by NEFCO.

Production data could not be provided by Mr. Jacobsen because the records are maintained in Seattle. On an average day, NEFCO processes 20,000 lbs of hand-butchered salmon and 187,500 lbs of canned fish (raw product). Hand-butchered fish are processed during one 12-hour shift with canning operations occurring over one 8-hour shift. Hand-butchered salmon yields 75 percent product and canned fish provide a 70 percent yield. During peak processing days, 30,000 lbs of salmon are hand-butchered and 420,000 lbs of fish are canned. Peak days involve one 18-hour shift for each commodity. On the average, seven peak processing days occur during the season.

NEFCO utilizes two model K chinks (90 fish per minute each) which are operated simultaneously to butcher fish. Fish are placed into cans by the available one-pound tall, two 1/2 lb or one 1/4 lb lines. Any three of these lines may be operated at once. For hand-butchered fish, six Dole plate freezers are used to process 30,000 lbs of raw fish per day. The salmon season normally extends from May 15 to September 15 each year. A small portion of the Sockeye heads are rendered for oil which is added to the canned salmon. Salmon eggs are cured and boxed for export to Japan.

All wastes generated by NEFCO are ground and discharged through a 6-inch flexible plastic hose, extending approximately 300 feet beyond the end of the pier. The outfall is stored at the end of each processing season. The outfall has been in use for the last five or six years. Prior to the purchase of the plastic hose, solids were discharged through a gurry trench which terminated at the end of the dock. Heads from the chinks are ground by two Autio 1101 grinders located adjacent to each machine. The ground heads and other wastes are directed to a 25 hp drum grinder before being pumped through the outfall. NEFCO appeared to be conscious of waste management with all floor drains and waste solids being directed to the grinder. At the present time, NEFCO employs an elevator system for unloading fish but will convert to a Temco pneumatic unit for the 1979 season.

NEFCO maintains its own water system to supply the plant. Water is captured from streams originating in the mountains adjacent to the plant. The collected water flows into a 50,000-gallon tank for storage. Mr. Jacobsen estimated the average water use at 250,000 gpd with a maximum consumption of 350,000 gpd.

Later, I visited Cordova City Hall to obtain pertinent information relative to the city and the processing plants. Cordova has an approximate population of 2,500 people. Mountains surround the city so it is not accessible by road. The four processing plants located in Cordova are: North Pacific, NEFCO, St. Elias and Morpac. In June 1976, approximately 950 of 2,500 people were employed. Approximately 200 residents were involved with the seafood processing industry at that time. There is one publicly-owned landfill site located 1/2 mile outside the city. However, the city is receiving pressure from state and federal agencies to close the dump. A primary treatment plant which is not capable of accomodating the process flows generated by the salmon canneries is also operated by the city.

August 3, 1978

During my visit to Cordova, I had the opportunity to speak with Mr. Don Endicott of Endicott Diving Company to discuss his recent (February 6, 1978) proposal for barging fish solids for the local processors. Mr. Endicott said that he had received an encouraging response from St. Elias; however, Morpac and NPP indicated they would only join in the barging operation if forced to. St. Elias has contacted a contractor to obtain a quote for a storage hopper which would be constructed at the end of the pier for dumping into the barge. Although NEFCO was not contacted by Mr. Endicott, he felt that they would consider his proposal if the other processors in Cordova had initiated efforts to do so.

Mr. Endicott's proposal was based on a 285-day processing season and prices were estimated on a per trip basis. He estimated that each cannery would be charged $73.93 per trip. The estimate includes: a 60-day season for Red salmon at two trips per day per cannery; a 30-day seining season at four trips per day per cannery; a 30-day Silver season at two trips per day per cannery; and a 165-day crab season at two trips per day per cannery. The total number of trips is 630, for an annual cost of $46,576 per cannery.

AN INVESTIGATION OF CERTAIN ASPECTS OF CRAB PROCESSING WASTE DISPOSAL PRACTICES: *IN SITU* AND *IN VITRO* RESPONSES OF *VIBRIO PARAHEMOLITICUS* AND *VIBRIO ANGUILLARUM*

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ABSTRACT

Current seafood processing operations in Alaska discharge untreated, or minimally treated, wastes into the waters adjacent to the site of operation. When wastes accumulate, markedly increased concentrations of soluble nutrients and hydrogen sulfide, and decreased concentrations of dissolved oxygen are observed. Sediment organic content increases with associated anoxia and visible sludge accumulation. Although these circumstances will result in increased microbial populations, the nature of the populations developing, and their possible hazards to the environment, are unknown.

This project utilized a dual approach, with the objectives of determining if pathogenic populations could develop in sediment where processing wastes accumulated. Field samples were analyzed for *Vibrio parahemolyticus* and coliforms, while *in vitro* techniques were utilized to determine if *V. parahemolyticus* and *V. anguillarum* could grow on nutrients supplied by the crab wastes at *in situ* temperatures.

Forty-six sediment samples were obtained from Dutch Harbor, Kenai, and Cordova, from areas adjacent to processing outfalls. No significant accumulations of coliforms were observed, and although *V. parahemolyticus* was not isolated from any sample, *V. alginolyticus* was isolated from one Cordova sample. Marked increases in the bacterial populations were observed in sediments where wastes accumulated.

Both *V. parahemolyticus* and *V. anguillarum* were shown to use crab processing wastes in sea water as nutrients. Although *V. parahemolyticus* grew well at 25 and 37°C, little or no growth was observed at either 5 or 10°C. *Vibrio anguillarum*, on the other hand, grew well at all temperatures tested.

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We thank Captain Ken Turner and the crew of the R/V *Acona* for sampling assistance in the vicinity of Dutch Harbor. The Publications Department of the Institute of Marine Science, University of Alaska, Fairbanks assisted in the final phases of the report.

SECTION 1

INTRODUCTION

Seafood processors in Alaska, with few exceptions, discard their processing wastes in waters near the processing site. In general, the wastes are simply piped to a depth of at least seven fathoms, although some processors screen and grind wastes to reduce effluent particulate size (1,2,3). At several locations, wastes have been shown to accumulate and to result in environmental changes associated with microbial activity, including nutrient and hydrogen sulfide accumulation, anoxia, and visible accumulations of debris (2,3). However, except for two reports (1,4), little is known about the nature of the developing microbial communities.

Vibrio spp. has long been associated with marine environments, particularly where chitinous material accumulates (1,5,6,7,8). *Vibrio parahemolyticus* and *V. anguillarum* have been pathogenically associated with humans (8) and marine organisms (9), respectively, the former being transmitted in contaminated seafoods. There is only one reported isolation of *V. parahemolyticus* and *V. alginlyticus* from Alaskan waters (1,4), although that study was limited to southeastern waters.

This project had as its specific objectives, (1) to attempt isolation of *V. parahemolyticus* from sediment samples obtained from processing waste disposal sites at Dutch Harbor, Kenai, and Cordova and (2) the determination of whether or not *V. parahemolyticus* and *V. anguillarum* would utilize crab waste products as nutrients in sea water, at temperatures approximating those found at the disposal sites.

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SECTION 2

CONCLUSIONS

1. *Vibrio parahemolyticus* was not isolated from any of forty-six samples of sediment from Dutch Harbor (18 samples), Kenai (14 samples) and Cordova (14 samples), although *V. alginolyticus* was isolated from one Cordova sample.

2. No significant accumulation of enteric bacteria was observed in any sample, although a marked increase in total bacterial biomass was observed in sediments where wastes accumulated.

3. *Vibrio parahemolyticus* could efficiently use crab meal as a nutritional source in sea water, producing good growth at 25° and 37°C, but not at 5° or 10°C.

4. *Vibrio anguillarum* could also use crab meal as a nutrient source, producing good growth at 5°C.

5. *Vibrio parahemolyticus* does not appear to be a health hazard at disposal sites in waters that remain below 10°C; however, isolation of *V. alginolyticus* from one sample suggests that current practices could become hazardous to humans at sites where water temperature exceeds 10°C.

6. Current disposal practices, in light of the growth of *V. anguillarum* under these conditions, may be assumed to create hazards to fish and susceptible marine fauna.

SECTION 3

RECOMMENDATIONS

1. Current seafood waste disposal practices should be improved to ensure dispersion of wastes by discharging effluent into waters with vigorous current flow.

2. Additional studies on the temperature requirements of *Vibrio parahemolyticus*, as well as the bacterium's susceptibility to temperature and osmotic changes should be encouraged.

3. Refined techniques for rapid isolation of *Vibrio* spp., especially *anguillarum*, from marine environments and food products should be developed.

SECTION 4

EXPERIMENTAL PROCEDURES

FIELD SAMPLES

Grab sediment samples were taken from Dutch Harbor, Alaska, by Dr. Howard Feder, University of Alaska, Institute of Marine Sciences, aboard the R/V *Acona*, and from Kenai and Cordova, Alaska, by Mr. Michael Caponigro, of S.C.S. Engineering, Long Beach, California, under contract with the Environmental Protection Agency. Exact locations of sampling sites and adjacent river outfalls and processing discharge sites are shown in Figures 1 through 3.

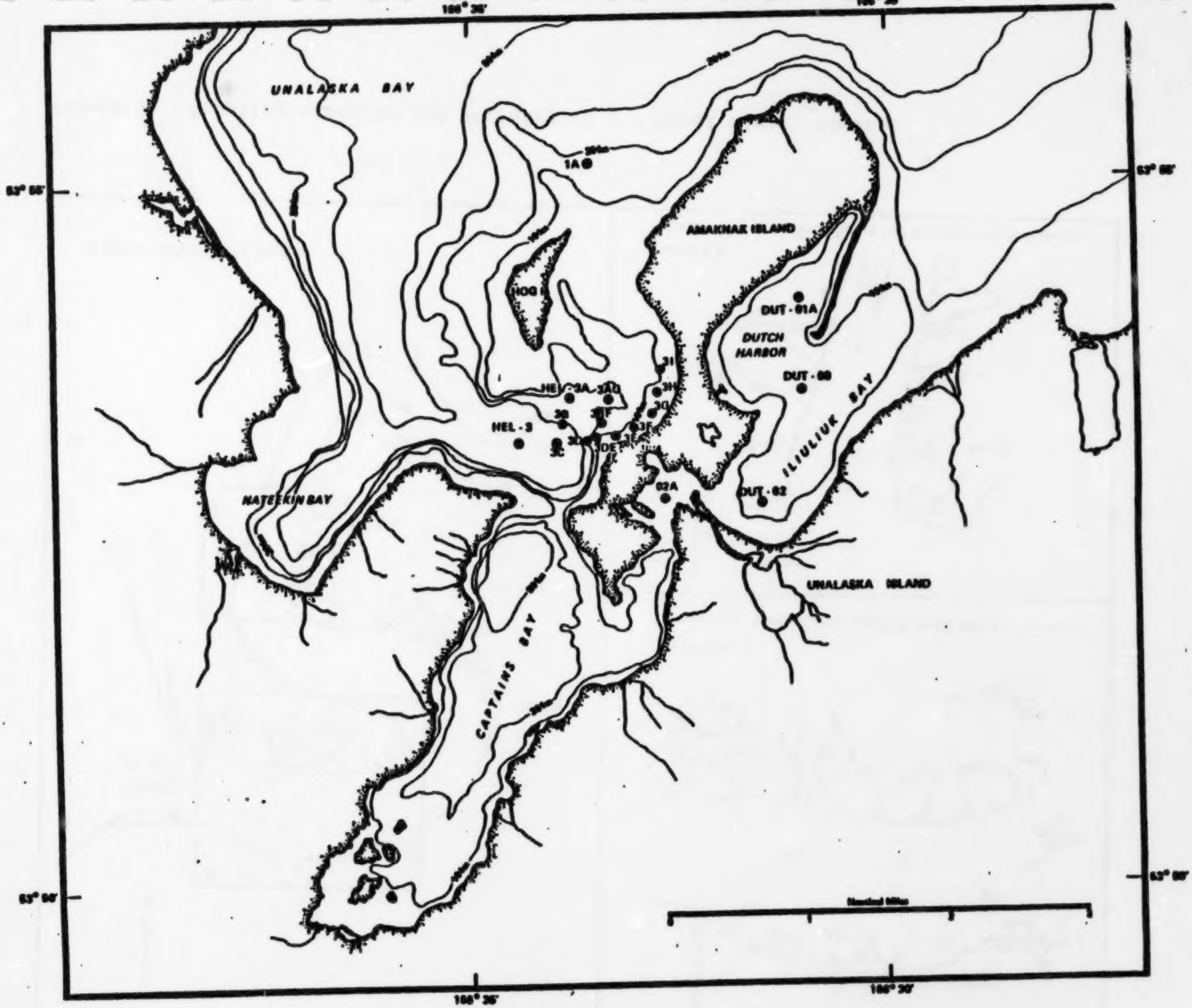
Fifty to one hundred gram portions of the samples, chosen to obtain surface (sediment-water interface) sediment were placed into sterile glass containers or Whirl-Pak bags and held for analysis. The Dutch Harbor samples were processed for *Vibrio* enrichment onboard immediately upon sample recovery, but other analyses and the Kenai and Cordova sample analyses were performed in Anchorage, no later than 72 hours after sampling. All samples were maintained at temperatures above 10°C until analysis for *Vibrio* was completed (10), and then stored at 4-5°C until discarded.

VIBRIO ENRICHMENT

Primary enrichment and Most Probable Number (MPN) analyses for *Vibrio* spp. was accomplished with techniques similar to those previously described (4,11), using alkaline peptone medium (APM), consisting of 0.5% tryptone, 0.25% yeast extract, 0.1% destrose in artificial sea water (Aquarium Systems, Inc., East Lake, Ohio), adjusted to pH 8.0. All tubes or bottles were streaked for isolation after 48 hours incubation at 25°C on TCBS agar (Difco). Typical green colonies on TCBS were picked, purified, and maintained for further study on sea water plate count agar (SWPC), made with Plate Count Agar (Difco) in artificial sea water, at pH 8.0.

Dutch Harbor samples were quantitatively assayed by suspending 10 g of sediment in 100 ml of APM and using aliquots of the resulting 1:10 suspension to inoculate a three tube - three set MPN series (0.1 ml, 1.0 ml, and 10.0 ml) made with APM. After 48 hours incubation, all tubes, as well as the original suspension, were streaked for isolation on TCBS and scored positive if oxidase positive, yellow or green *Vibrio*-like colonies developed.

Samples from Kenai and Cordova were subjected to primary enrichment by suspending 10 g in APM and streaking for isolation after 48 hours, as previously described.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3AD
3B
3F
3I
3H
3G
HEL - 3
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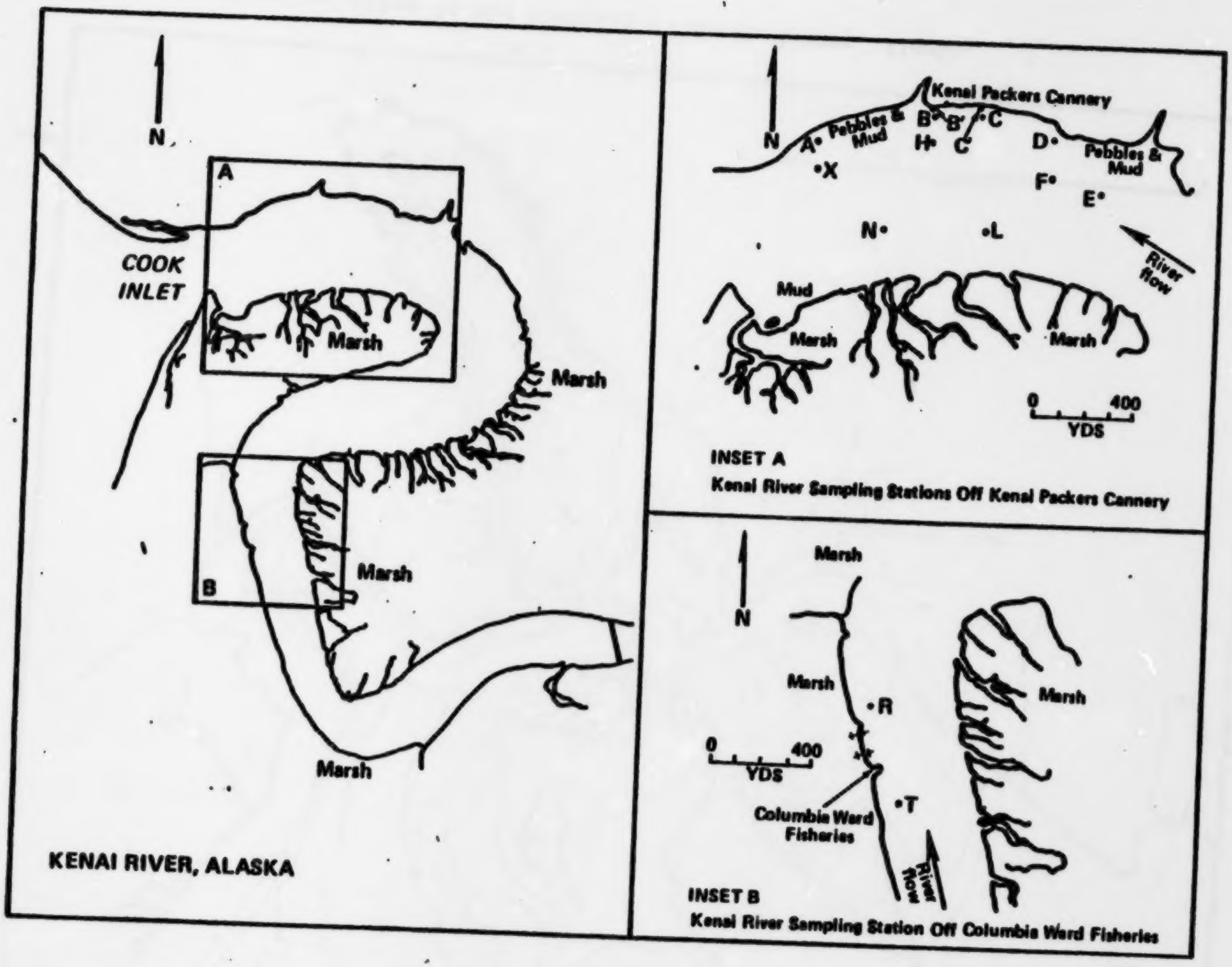
02A
NATEEKIN BAY
CAPTAINS BAY
UNALASKA ISLAND
Nautical Miles

Figure 1. Sampling sites in the vicinity of Dutch Harbor, Alaska.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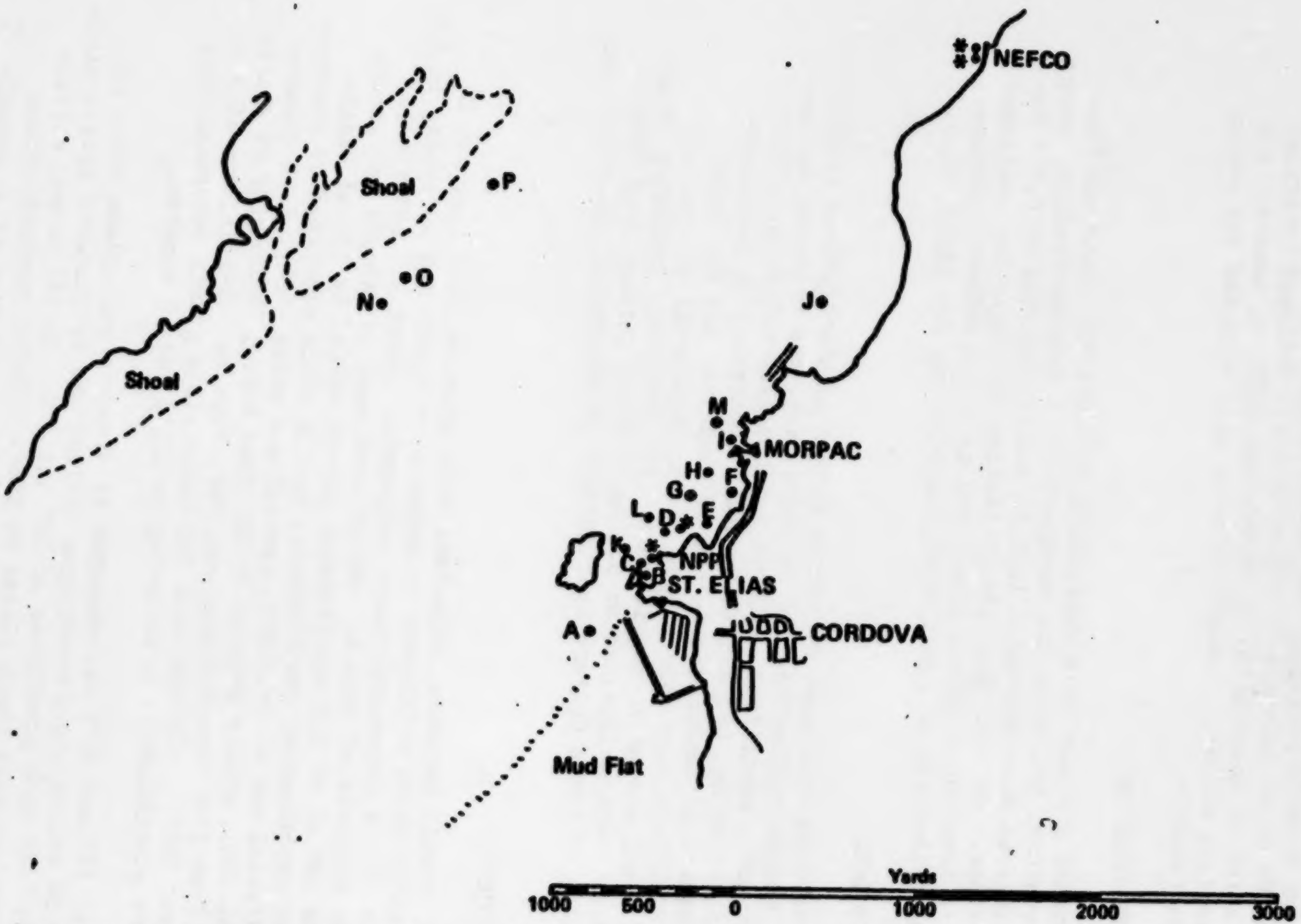
Columbia Ward Fisheries
River flow
Marsh

INSET A
Kenai River Sampling Stations Off Kenai Packers Cannery

INSET B
Kenai River Sampling Station Off Columbia Ward Fisheries

Figure 2. Sampling sites in the vicinity of the Kenai River, Alaska.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C
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A•
CORDOVA
Mud Flat
Yards
1000
500
0
1000
2000
3000

*End of outfall at St. Elias, NPP and Nefco canneries.

Figure 3. Sampling sites in the vicinity of Cordova, Alaska.

ENTEROBACTERIACEAE ENRICHMENT

Enrichment for enteric pathogens was accomplished by suspending 10 g of sediment into 100 ml of Selenite F Medium (Difco), followed by streak plate isolation after 48 hours at 37°C, on Bismuth Sulfite, Hektoen, and MacConkey's agars (all Difco). Suspect colonies were streaked for purity on Hektoen and MacConkey's.

BIOCHEMICAL IDENTIFICATION

All biochemical profiles were determined with API-20E (Analytab Products) culture systems, following the manufacturer's recommendations, except that all TCBS isolates were suspended in 3.5% saline (instead of 0.9%) for the API inoculations. In addition, identification of *Vibrio* was confirmed by sensitivity to Novobiocin (Difco discs) and to 2,4-diamino-6-7-diisopropyl pteridine (Vibriostatic Agent 0/129, Calbiochem, San Diego, Ca.).

CULTURES AND CONTROLS

Positive controls were made by adding *Vibrio parahemolyticus* (ATCC: 17802) to some sample replicates, and in every case, the organism was recovered and correctly identified. *Vibrio parahemolyticus* (ATCC: 17802) was kindly supplied by Ms. Lee Anne McGonagle, Department of Laboratory Medicine, University of Washington School of Medicine, and Dr. Roger Grischkowsky, Fish Pathology Laboratory, Alaska Department of Fish and Game, supplied a culture of *V. anguillarum*. All cultures, including environmental isolates, were maintained on Sea Water Stock Culture Agar (SWSC) stabs, consisting of Stock Culture Agar (Difco) in artificial sea water, at pH 8.0.

IN VITRO EXPERIMENTS

For experimental purposes, organisms were grown on SWPC agar for 24 to 48 hours, after which sufficient colonies were picked and suspended into 3.5% saline to give a moderately heavy suspension (about 10^5 cells/ml). One milliliter aliquots of this suspension were used as inocula for growth experiments in 100 ml of the experimental growth media, in 250 ml flasks. Depending upon experimental requirements, growth media consisted of combinations of artificial sea water (ASW), natural sea water (NSW), 1.0% commercial crab meal (CM), kindly donated by Dr. Fred Husby, University of Alaska Experimental Farm from Seward Fisheries, Inc. (Lot No. CO-355), and 10 g of marine sediment (SED). APM was used for comparative growth determinations. All media were sterilized by autoclaving at 121°C for 15 minutes.

Growth at 37° and 25°C was measured by standard pour plate count procedures in 3.5% saline plate count agar (Difco) and by standard spread plate techniques on TCBS when growth was at 10° and 5°C. In all cases, culture purity was verified with check plates on TCBS. *Vibrio parahemolyticus* colonies were counted after 48 hours at 37°C, and colonies of *V. anguillarum* were counted after 72 hours at 25°C.

SECTION 5

RESULTS

FIELD SAMPLES

Dutch Harbor

Nineteen samples were obtained for analysis for *Vibrio* spp., pH, and total heterotrophic counts of selected sub-samples. These results are summarized in Table 1. Six samples had populations of *Vibrio*-like isolates that were lower than could be counted with a three tube MPN series, and three of these were also negative when the initial 1:10 enrichment was plated. Conversely, five samples had populations exceeding the resolution of the three tube set. The results of the *Vibrio* MPN tests correlated well with physical appearance and odor of the samples and with total heterotrophic counts, which showed that those samples with highest *Vibrio*-like colonies had more than 100 times as many colonies by plate count enumeration. Analysis for coliforms (MPN-3 tube-Brilliant Green Bile Lactose), however, showed all samples to be free of significant coliform contamination.

Kenai

Fifteen sediment samples were obtained (S.C.S. Engineers, Long Beach, Ca.) from areas adjacent to the Kenai processing facilities (see Fig. 2A, B,C), for qualitative analysis for *Vibrio parahemolyticus* and pathogenic coliforms. Although seven samples produced green colonies on TCBS after enrichment, only one proved to be oxidase positive after sub-culture and was identified as being of the *Pseudomonas fluorescens* group by API analysis. *Vibrio parahemolyticus* was not detected in any sample. Six samples produced suspect colonies on Bismuth Sulfite Agar, but further analysis with Hektoen Agar, and API analysis identified them as *Citrobacter freundii* and *Pseudomonas fluorescens*. These results are shown in Table 2.

Cordova

Sixteen samples were obtained (S.C.S. Engineers, Long Beach, Ca.) from areas adjacent to Cordova processing facilities and subjected to qualitative analysis for *V. parahemolyticus* and pathogenic Enterobacteriaceae. Three samples produced suspect colonies on TCBS, but were subsequently identified as *P. putrefaciens* and *P. fluorescens*. Seven samples produced suspect colonies on Bismuth Surfite, MacConkeys, or Hektoen and were identified as shown in Table 3. *Vibrio alginolyticus* was isolated from one sample (CE). Reisolation and reidentification confirmed the original findings.

TABLE 1. ANALYSIS OF DUTCH HARBOR SEDIMENT FOR pH, *VIBRIO*, TOTAL COLIFORMS, AND TOTAL HETEROTROPHIC COUNTS

Sampling Dates 6/11/78-6/12/78

Sample No.	pH*	*Vibrio*; MPN/100 ml (of a 1:10 susp.)	Coliform MPN/100 ml	Total CFU/ml (Lg10 #)	Mean Total CPU/ml (Lg10 #)
HEL 3AG	7.3	240			
HEL 3	7.5	460			
HEL 3BF	7.09	150			
HEL 1A	7.04	9			
HEL 3H	7.38	75			
HEL 3D	7.12	460			
HEL 3A	7.09	1,100			
HEL 3C	7.77	150			
HEL 3DE	6.64	<3.0*			
DUT 02A	7.01	93			
HEL 3E	7.14	<3.0†	23	3.39	
DUT 01A	7.40	<3.0†	9	2.35	2.85 ± 0.58
DUT 02	7.50	<3.0†	23	2.30	
DUT 00	7.30	<3.0†	9	3.25	
HEL 3F	7.08	>1100	23	5.25	
HEL 3G	7.06	>1100	9	4.82	5.07 ± 0.19
HEL 3I	7.03	>1100	9	5.18	
HEL 3B	7.10	>1100	4	5.03	

*pH taken at 72 hrs after sampling.

†Of those samples showing less than 3.0 *Vibrio*/100 ml, three (DUT 02, DUT 00, DUT 101) yielded no growth of *Vibrio*-like colonies on TCBS streaks of the original 1:10 suspension. All others were positive at 1:10.

TABLE 2. ANALYSIS OF KENAI SEDIMENT SAMPLES

Sampling Dates 7/25-26/78

	VIBRIO SCREEN		COLIFORM SCREEN		
Sample No.	TCBS Plates	Final API Analysis	Bismuth Sulfide Screen	Mac/Hek* Screen	Final API Analysis
A	-		-		
B	-		-		
B_1	+	Oxidase Negative	+	Non-LF†	*Pseudomonas fluorescens*
C	-		-		
C_1	+	Oxidase Negative	-	LF	*Citrobacter fruendii*
D	+	Oxidase Negative			
E	+	*Pseudomonas fluorescens*	+	Non-LF + LF	*Ps. fluorescens* and *Cit. fruendii*
F	-		-		
H	-		-		
L	-		+	LF	*Citrobacter fruendii*
N	+	Oxidase Negative	+	LF	ND
R	-		-		
T	-		+	Non-LF	*Ps. fluorescens*
X	-		-		

*MAC = MacConkey's AGAR; HEK = Hektoen AGAR

†LF = Lactose Fermenter

TABLE 3. ANALYSIS OF CORDOVA SEDIMENT SAMPLES

Sampling Dates 7/28-8/2/78

Sample No.	Temp.* Celsius	Depth* Meters	*VIBRIO* SCREEN TCBS Plates	*VIBRIO* SCREEN API Analysis	COLIFORM SCREEN Bismuth Sulfide MAC/HEK†	COLIFORM SCREEN API Analysis
CA	11.6	65	-		-	
CC	11.7	125	-		-	
CD	11.9	8.7	-		-	
CE	na	na	-		+	*V. alginolyticus*
CG	na	na	-		-	
CH	11.9	6.75	+	*Ps. putrefaciens*	+	LF†
CI	11.4	7.5	-		-	
CJ	11.1	10.2	-		-	
CK	11.6	8.5	-		+	*Achromobacter* sp.
CL	11.9	8.0	+	*Ps. putrefacieus*	+	LF
CM	11.8	18	+	*Ps. fluorescens*	-	
CN	11.4	9.5	-		-	
CO	11.7	8	-		-	
CP	na	na	-		+	*Ps. putrefacieus*
NPP	na	na	-		+	*Ps. putrefacieus*
St. Elias	na	na	-		+	*Ps. fluorescens*

*Data supplied by S. C. S. Engineers.

†Abbreviations as in Table 2.

IN VITRO EXPERIMENTS

Tolerance of Reduced Salt Concentration by *Vibrio parahemolyticus*

Viability of *V. parahemolyticus* was tested in artificial seawater, 3.5% NaCl, 0.85% NaCl, and distilled water by both qualitative (Table 4) and quantitative (Table 5) determination of viable colony forming units. No difference could be detected between sea water, 3.5% NaCl or 0.85% NaCl as a suspending medium, but suspension in distilled water resulted in a rapid loss of viability. However, when 3.5% NaCl and 0.85% NaCl were used as the suspending medium for API analysis, abnormal biochemical profiles (Table 6) were observed with 0.85% saline, but not with 3.5% saline. In this experiment, four cultures of *V. parahemolyticus* in 0.85% NaCl, resulted in abnormal API profiles at 24 hours, resembling that commonly observed with some pseudomonads. All tests remained negative at 48 hours.

TABLE 4. EFFECT OF SALINE CONCENTRATION OF SUSPENDING MEDIUM ON SURVIVAL OF *VIBRIO PARAHEMOLYTICUS* - QUALITATIVE ASSAY

	Time, min.					
Suspension	0	5	10	30	60	90
Distilled Water	4+	1+	-	-	-	-
Artificial Seawater	4+	4+	4+	4+	4+	4+
3.5% Saline	4+	4+	4+	4+	4+	4+

TABLE 5. EFFECT OF SALINE CONCENTRATION OF SUSPENDING MEDIUM ON SURVIVAL OF *VIBRIO PARAHEMOLYTICUS* - QUANTITATIVE ASSAY

	Time, min.			
Suspension	0	20	60	120
Distilled Water	4.80*	1.50	1.30	0
0.85% Saline	5.10	5.40	5.20	5.40
3.50% Saline	5.20	4.90	5.30	5.30

*Numbers are $\log_{10}$ numbers of cells, determined by pour plate technique.

Bacterial Content of Crab Meal

The crab meal used in this project was analyzed for bacterial content and was found to produce 3.1×10^6 CFU/ml by total count, 2.0×10^1 CFU/ml on Bismuth Sulfite Agar and 1.75×10^5 *Vibrio*-colonies on TCBS agar. *Vibrio parahemolyticus* was not detected. The suspect colonies on Bismuth Sulfite were identified as *Enterobacter cloacae* by API, but the yellow colonies produced on TCBS did not key out, although they were Gram negative, oxidase positive rods. No further analysis of the crab meal was attempted and when used in subsequent experiments, it was sterilized by autoclaving.

TABLE 6. BIOCHEMICAL PROFILE ON API-20E OF SELECTED ISOLATES FROM ORIGINAL CULTURE OF *VIBRIO PARAHEMOLYTICUS*

Culture Reisolate	API Inoculum Diluet	API Profile Identification
Vp-01	0.85% Saline	All tests negative at 24 and 48 hrs
	3.50% Saline	*V. parahemolyticus* (profile No. 4356106)
Vp-02	0.85% Saline	All tests negative at 24 and 48 hrs
	3.50% Saline	*V. parahemolyticus* (Profile No. 4356106)
Vp-A	0.85% Saline	All tests negative at 24 and 48 hrs
	3.50% Saline	*V. parahemolyticus* (Profile No. 4356106)
Vp-37I	0.85% Saline	All tests negative at 24 and 48 hrs
	3.50% Saline	*V. parahemolyticus* (Profile No. 4356106)

Growth of *V. parahemolyticus* in Sea Water and Crab Meal Based Media

The data in Table 7 and Figure 4 show that *V. parahemolyticus* is quite able to utilize commercially available crab meal as a nutrient source. In these experiments, the crab meal was not treated in any way (other than during preparation by the manufacturer) except that the test media (sea water + 1% Crab Meal) were sterilized by autoclaving prior to use. The apparent increase in number of colony-forming-units in non-supplemented sea water is unexplained, although it suggests the *V. parahemolyticus* is an efficient saprophyte, quite able to scavange the small amounts of nutrients present in sea water. Nevertheless, growth in 1% crab meal was dramatic, resulting in up to a five-log (100,000x) increase in cell number in 96 hours. Also, it can be seen that little or no difference can be observed between the growths obtained in natural or artificial sea water. It would also appear that the crab meal was a better nutrient than alkaline peptone medium, although the reasons for this were not pursued in this project.

Growth of *V. parahemolyticus* at 5, 10 and 25°C

Tables 8 through 10 and Figure 5 show the growth of *V. parahemolyticus* at temperatures related to *in situ* temperatures of Alaskan waters. Although this strain of *Vibrio* could grow quite well at 25°C (Table 10), no growth was observed, at 5°C (Table 8) and 10°C (Table 9), for up to 96 hours. However, our data show that *V. parahemolyticus* in sea water media is also able to survive for up to 96 hours, with no appreciable loss of viability at 25°C and at 10°C, and with only moderate loss at 5°C.

TABLE 7. GROWTH OF *VIBRIO PARAHEMOLYTICUS* AT 37°C IN ARTIFICIAL AND NATURAL SEAWATER-BASED MEDIA

	Time, Hrs						
Medium	3.0	6.0	8.5	24	48	72	96
ASW*	3.23†	3.49	3.21	4.56	4.89	4.84	4.83
ASW + CM	3.51	4.75	5.49	nd	6.72	7.84	7.45
NSW	3.18	3.59	3.54	3.48	4.51	4.46	4.05
NSW + CM	3.53	4.76	5.57	nd	7.43	7.61	7.40
APM	3.53	4.53	5.31	nd	5.82	4.67	4.51

Count at 0 hrs = 3.18

*Abbreviations: ASW = Artificial Seawater; CM = Crab Meal; NSW = Natural Seawater; APM = Alkaline Peptone Medium.

†Numbers are $\log_{10}$ number of colony forming units/ml.

TABLE 8. GROWTH OF *V. PARAHEMOLYTICUS* AT 5°C IN ARTIFICIAL SEAWATER AND CRAB MEAL MEDIUM

Time, hrs	Artificial Seawater	Artificial Seawater & Crab Meal
0	4.03*	4.03
1.5	4.10	4.19
3.0	4.10	4.25
7.0	4.08	3.93
24.0	2.88	3.78
48.0	3.72	2.70
72.0	3.70	3.00

*Numbers are $\log_{10}$ number of colony-forming-units/ml.

TABLE 9. GROWTH OF *V. PARAHEMOLYTICUS* AT 10°C IN ARTIFICIAL SEAWATER AND ARTIFICIAL SEAWATER AND CRAB MEAL MEDIUM

Time, hrs	Artificial Seawater	Artificial Seawater and Crab Meal
0	6.10*	6.10
6	6.10	6.40
24	6.90	7.10
45	5.90	6.20
69	6.40	5.70
96	6.80	6.00

*Numbers are $\log_{10}$ number of colony-forming-units/ml.

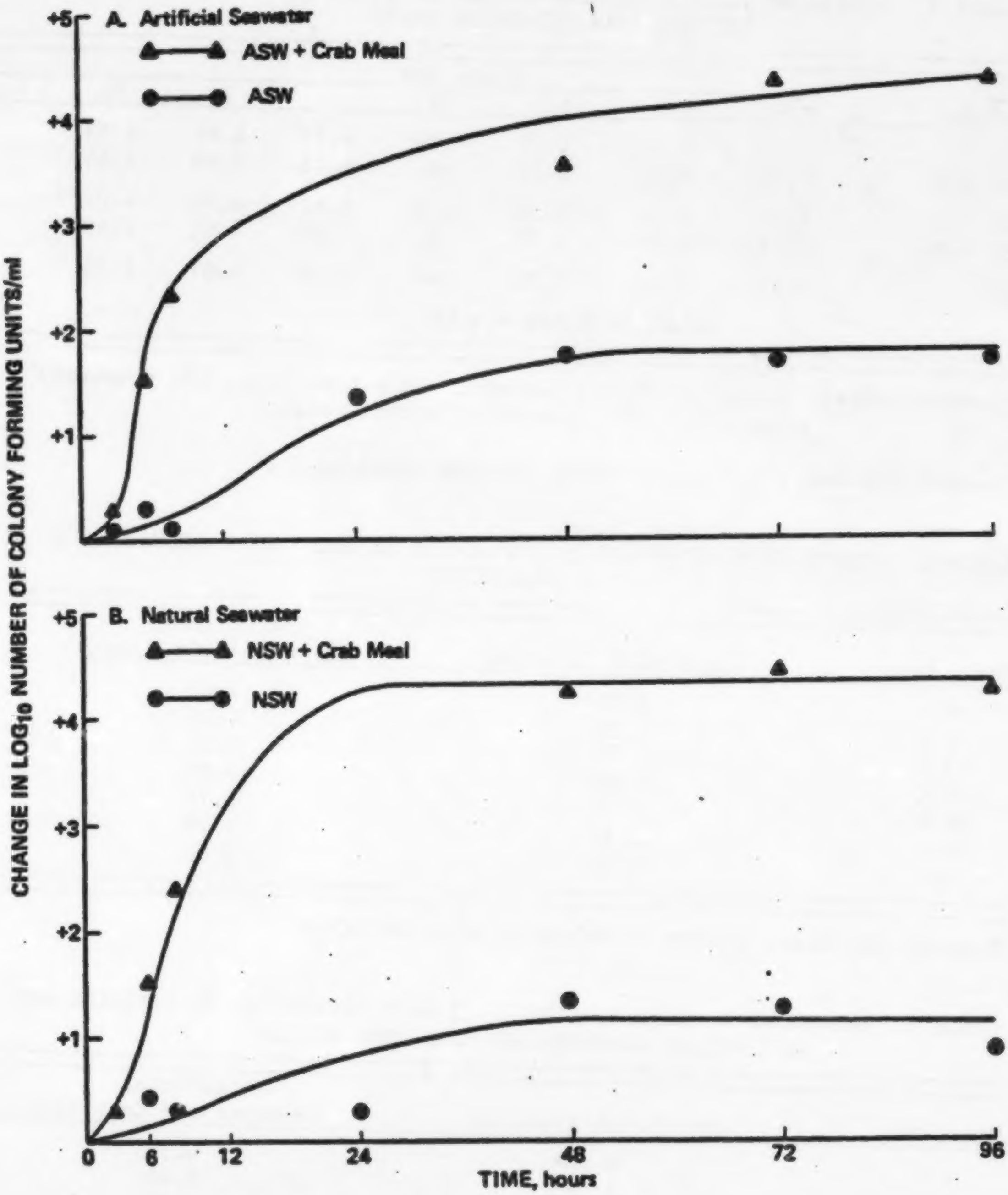

Figure 4. Growth of *Vibrio parahemolyticus* at 37°C in crab meal supplemented artificial and natural seawater.

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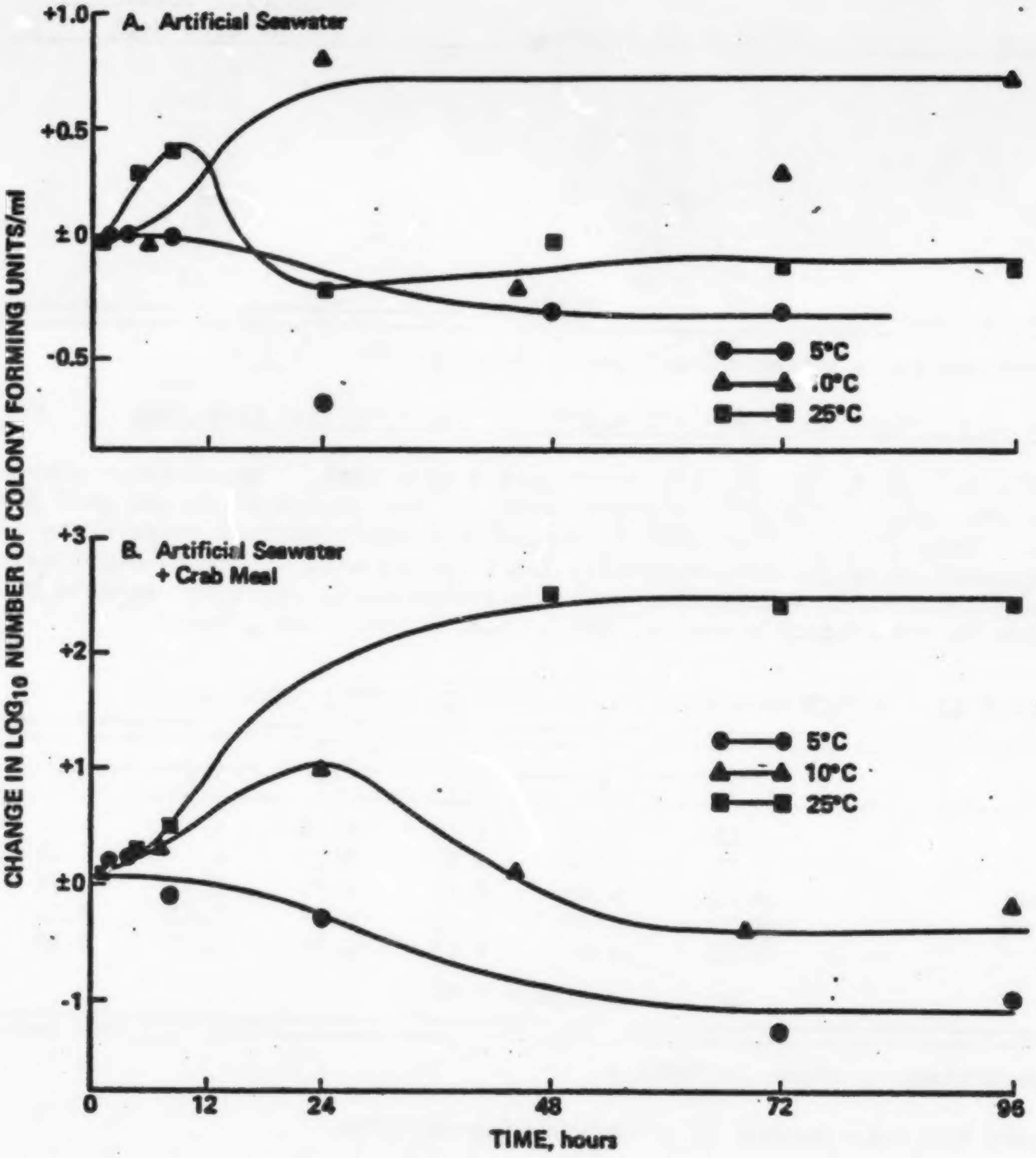

Figure 5. Growth of *Vibrio parahemolyticus* at 5°, 10°, and 25°C in artificial seawater and artificial seawater and crab meal.

TABLE 10. GROWTH OF *V. PARAHEMOLYTICUS* AT 25°C IN ARTIFICIAL SEAWATER AND ARTIFICIAL SEAWATER PLUS CRAB MEAL MEDIUM

Time, hrs	Artificial Seawater	Artificial Seawater Plus Crab Meal
0	5.14*	5.14
1	5.26	5.20
4	5.43	5.47
7	5.49	5.67
24	4.99	na
48	5.10	7.61
72	5.00	7.57
96	4.96	7.59

*Numbers are $\log_{10}$ number of colony-forming-units/ml.

Growth of *V. anguillarum* at 25°C and 5°C in Sea Water and Crab Meal

The data in Tables 11, 12, and Figure 6 show that *V. anguillarum* grew well in the crab meal medium and, although some lag was observed, showed good growth at 5°C. This is consistent with *V. anguillarum* lower optimal temperature and temperature range characteristics (as compared with *V. parahemolyticus*) and suggests that this organism, or other cold-adapted saprophytes would be expected to proliferate where conditions similar to these prevail.

TABLE 11. GROWTH OF *VIBRIO ANGUILLARUM* IN SEVERAL MEDIA AT 5°C

	Time, hrs					
Medium	4	6	8.5	24	48	72
ASW*	4.15†	4.30	5.10	4.48	4.64	4.69
NSW	3.36	3.92	3.98	3.23	4.15	4.16
ASW+CM	4.11	4.00	4.34	4.76	5.62	6.71
NSW+CM	4.19	4.30	4.32	4.48	5.17	6.72
APM	4.43	4.46	4.15	4.70	5.59	6.99
	Count at 0 time = 4.22					

*Abbreviations as shown in Table 7.

†Numbers are $\log_{10}$ number of colony-forming-units/ml.

TABLE 12. GROWTH OF *VIBRIO ANGUILLARUM* IN SEVERAL MEDIA AT 25°C

	Time, hrs					
Medium	3	6	9	24	48	72
ASW*	4.28†	4.43	nd	4.26	4.38	nd
NSW	4.15	4.08	nd	4.36	4.20	4.11
ASW+CM	4.56	4.49	5.72	6.41	6.40	6.04
NSW+CM	4.32	5.19	5.83	6.85	6.04	6.63
APM	4.54	5.26	6.53	7.33	6.88	7.09
Count at 0 time = 3.98						

*Abbreviations as shown in Table 7.

†Numbers are $\log_{10}$ number of colony-forming-units/ml.

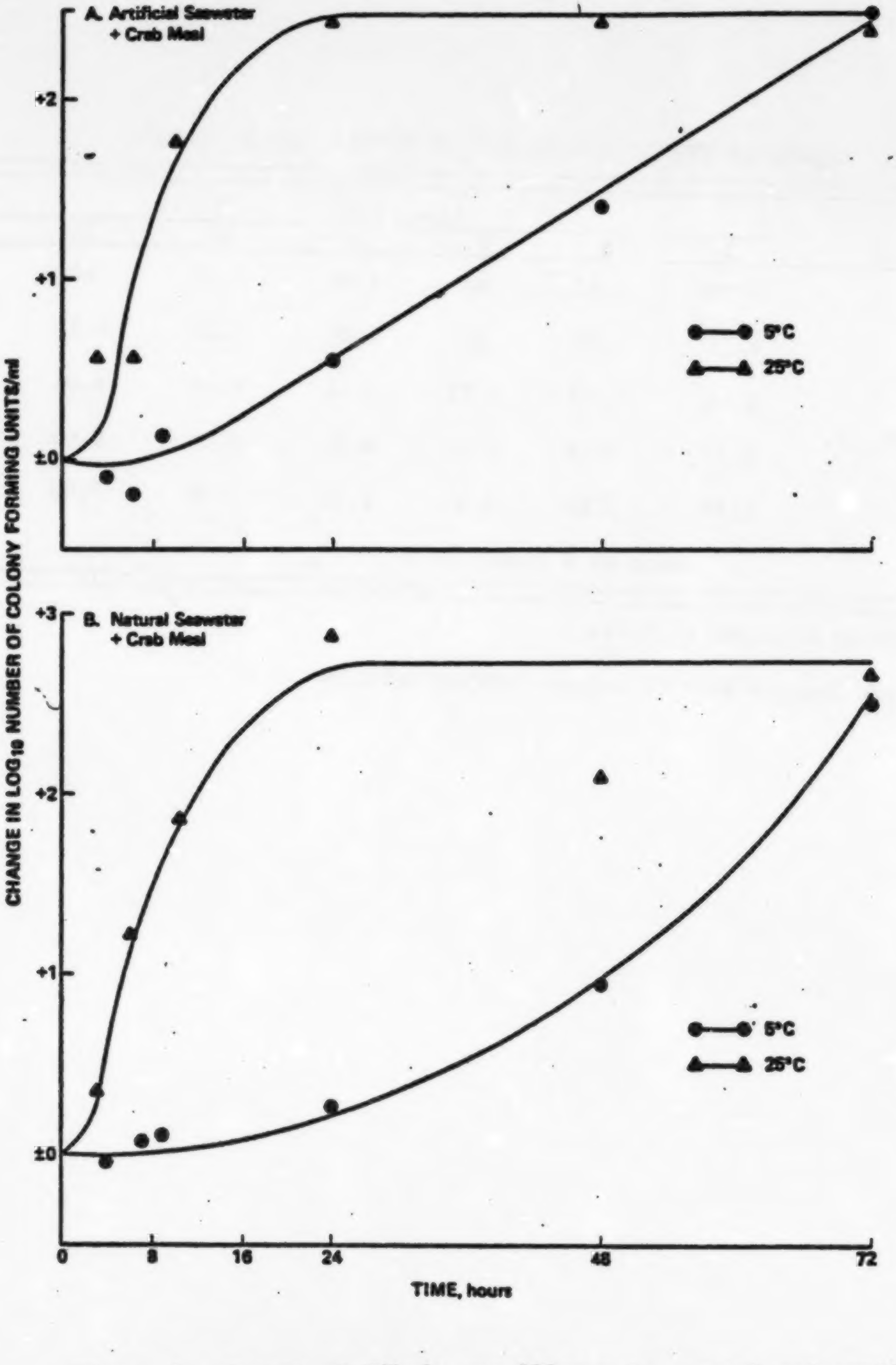

Figure 6. Growth of *Vibrio anguillarum* in natural and artificial seawater media, with crab meal, at 5° and 25°C.

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SECTION 6

DISCUSSION OF RESULTS

FIELD SAMPLES

Vibrio parahemolyticus was not isolated from any of forty-six sediment samples obtained from three locations associated with seafood processing wastes at Dutch Harbor, Kenai, and Cordova, Alaska. However, the isolation of *V. alginolyticus* from a single Cordova sample deserves careful attention. *Vibrio alginolyticus* is considered a biotype of *V. parahemolyticus* differing from *parahemolyticus* in salt tolerance, the reactions in MR-VP medium (12), and sucrose fermentation. Since fermentation of sucrose is at least partly responsible for the differences in colony colors on TCBS, the possibility that some of the yellow colonies observed in these samples were, in fact, *V. alginolyticus*, must be considered. That is, the organism may be more common than appears to be the case, because the screening used in this project selected for *V. parahemolyticus*-like green colonies and disregarded yellow colonies. Similar considerations apply to *V. anguillarum*, which also forms yellow colonies on TCBS. Thus, while *V. parahemolyticus* could not be detected in any sample, the techniques used here did allow for easy recovery of other *Vibrio*, especially *V. anguillarum* and *V. alginolyticus*. Considering the nature of the added nutrients, the enrichment of the microbial population for chitinolytic bacteria, such as *Vibrio* is to be expected (6,7) and in fact, was observed. However, the growth of *V. parahemolyticus* and *V. alginolyticus* should be restricted to areas where the temperature remained above 10°C (8) for significant periods of time. Organisms such as *V. anguillarum* which are able to grow at 5°C, must be considered as possible inhabitants of sediment and waters in which seafood wastes have been allowed to accumulate. (See section on *in vitro* studies for further discussion.) These studies indicate that current practices of sea-food waste disposal have not, of yet, created a health hazard to humans, at least, under present criteria. There was no successful isolation of *V. parahemolyticus* (although "added-in" controls produced positive isolates) or significantly increased enteric populations at the sites. However, the severe pollution reported previously (2,3) was confirmed by markedly increased heterotrophic bacterial counts (Table 4) and increased numbers of *Vibrio*-like organisms (Table 4). Dramatic changes in environmental conditions occurred wherever disposal practices resulted in accumulation of wastes.

PHYSIOLOGICAL ECOLOGY OF *VIBRIO* SPP.

One major objective of this project was to determine if *Vibrio parahemolyticus* or *Vibrio anguillarum* could grow under conditions similar to those occurring at the disposal sites. The genus *Vibrio* is characterized, in part, as being chitinolytic and associated with invertebrate exoskeleton material

(5,6). Furthermore, *V. parahemolyticus* has been reported to be mesophilic while other *Vibrio* are psychrophylic to varying degrees. It is generally believed that ambient water temperature at the disposal site will determine which species of *Vibrio* will predominate and that seasonal fluctuations in temperatures have been associated with seasonal appearances of *V. parahemolyticus* (7) and associated cases of enteritis (9,10).

The results obtained in this project confirm the previous reports that *V. parahemolyticus* was unable to replicate at either 5° or 10°C, but grew very well at 25° and 37°C in a sea water-crab meal medium (Figs. 4 and 5). *Vibrio anguillarum*, however, was able to replicate at 5°C and presumably could do so *in situ*. The isolation of *V. alginolyticus* from Cordova sediment may or may not indicate that *V. parahemolyticus* can grow at that location. The two organisms have different salt tolerances and different temperature tolerances (13).

These studies also indicate that *V. parahemolyticus* can very effectively use crab processing wastes in sea water as nutrients when the ambient temperature exceeds the minimum growth temperature. Although our data show that when the temperature does not exceed 10°C, *V. parahemolyticus* will not grow, we were unable to determine the exact minimum growth temperature for this organism, but caution that it may not be very much higher than 10°C.

There is little doubt, however, that the fish pathogen (9,10) *V. anguillarum*, can grow at 5°C and that the accumulation of sea food wastes could result in establishing a focus source of this organism, with resulting risk to local populations of marine organisms.

This project also demonstrated some of the problems that arise when studying marine organisms. Reports of osmotic and temperature damage and (14,15, 16) the prevention of, or compensation for, such damage have recently appeared. Our data suggest (Table 7) that although suspension of *V. parahemolyticus* in 0.9% NaCl has little observable effect on viability as measured by plate counts on osmotically suitable media (in this case TCBS and alkaline peptone-sea water agar), viability may be seriously affected when other more restrictive media are used or when diagnostic systems are used with 0.9% NaCl. The critical nature of the medium used subsequent to osmotic or temperature shock, as observed here, deserves careful consideration when developing diagnostic systems. In our laboratory, diagnosis of *Vibrio parahemolyticus* by API on 0.9% NaCl was simply not reliable. The necessity of using inocula containing cells in logrithemic growth, presumably to ensure good continued activity in the API system has also reported by Murray (17).

GENERAL ECOLOGICAL CONDITIONS

These studies, like all such studies that use pure cultures and laboratory conditions, can be applied to *in situ* situations in only a very limited way. For example, although our data show that *V. anguillarum* can replicate at 5°C, on crab wastes, the data do not measure the relative competitiveness of this organism *in situ*. It would be desirable to know its growth rate relative to other saprophytic bacteria occupying the same or a similar niche.

Although these studies suggest that *Vibrio parahemolyticus* will not grow at 10°C or lower, the data do not necessarily support a converse conclusion - that is, that *V. parahemolyticus* will necessarily appear if the water temperature exceeds 10°C. Again, knowledge of relative growth rate and competitiveness in a mixed population is necessary before such speculation would have any value. The data reported here only indicate that so long as the temperature remains at, or below, 10°C, it is unlikely that *V. parahemolyticus* will grow.

Finally, of course, growth will occur only where sufficient and appropriate nutrients are supplied. These data suggest, as hopefully other studies will prove, that dispersal of wastes by current flow will very effectively prevent the development of large bacterial populations and the problems associated with such a condition.

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